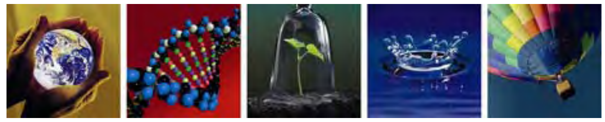

Sediment Trap Pilot Project Feasibility Study for the Saginaw River, Michigan

Prepared for:

ADR Technical Workgroup

Prepared by:

ENVIRON International Corporation
Chicago, IL

LimnoTech
Ann Arbor, MI

Date:

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ACRONYMS AND ABBREVIATIONS

ACSM	American Congress on Surveying and Mapping
ADCP	Acoustic Doppler Current Profiler
ADR	Alternative dispute resolution
ASTM	American Society for Testing Materials
BC	Black carbon
B	Brown clay with trace gravel and cobbles
CDF	Confined disposal facility
cfs	Cubic feet per second
cm	Centimeters
CY	Cubic yards
DMDF	Dredge material disposal facility
Dow	The Dow Chemical Company
EDI	Equal-discharge-increment
ENVIRON	ENVIRON International Corporation
ft	Feet
G	Gray silty clay and sandy silt
GPS	Global Positioning System
GSC	Gray silt/clay
HYPACK	Coastal Oceanographic’s HYPACK®
HRGC	High-resolution capillary column gas chromatography
HRMS	High-resolution mass spectrometry
IGLD	International Great Lakes Datum
kg	Kilogram
LISST-100	Laser In-Situ Scattering and Transmissometry
LWD	Low Water Datum
LTI	LimnoTech (formerly Limno-Tech, Inc.)
MDEQ	Michigan Department of Environmental Quality
MDNR	Michigan Department of Natural Resources
µm	Micrometer
m3	Cubic meter
mg/l	Milligrams per liter
mm	Millimeter
ng/kg	Nanogram per kilogram; or, part per trillion
OBS	Optical back scatter
OSI	Ocean Surveys Inc.
OS I	Gray to brown silt and clay with shells and organic material
OS II	Gray to brown sand with shells and organic material
OTB	Ojibway Island turning basin
PCB	Polychlorinated biphenyl

PCDD/Fs	Polychlorinated dibenzo-p-dioxins (PCDDs) and furans (PCDFs)
PCDD/F	Dioxin/furan
ppt	Parts per trillion
PSD	Particle size distribution
QA/QC	Quality assurance/quality control
QTI	Quantitative Technologies, Inc.
RM	River mile
RTK	Real time kinematic
SSC	Suspended sediment concentrations
SSTB	Sixth street turning basin
TCDD	2,3,7,8-Tetrachlorodibenzodioxin
TEF	Toxic equivalency factor
TEQ	Toxic equivalence
TOC	Total organic carbon
TM17	Mass of the 17 dioxin/furan congeners with TEF values
TSS	Total suspended solids
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
WHO	World Health Organization

1 Introduction

1.1 Background

This report summarizes the results of a 16-month field investigation—under the auspices of the Alternative Dispute Resolution (ADR) process—to assess the feasibility of maintaining a large-scale sediment trap in the Saginaw River, Michigan. The Technical Workgroup,[1] whose members include scientists and engineers representing various state and federal agencies, the Saginaw Chippewa Indian Tribe, and The Dow Chemical Company (Dow), conducted the pilot study in the Sixth Street Turning Basin (SSTB) of the Saginaw River to answer questions concerning the use of navigation turning basins as sediment traps to capture and remove sediment, reduce downstream maintenance dredging requirements for maintaining navigation channels, and remove contaminants associated with captured sediment. Emergency dredging by The United States Army Corps of Engineers (USACE) of the SSTB in August–September 2006 provided a unique opportunity to evaluate its performance as a sediment trap.

In general, sediment traps may be employed wherever it is desirable to manage sediment deposition and transport (Parchure 2002). Implementation of an effective sediment trap can allow for the collection of sediments at a single location to reduce downstream maintenance dredging requirements for maintaining navigation channels. Sediment traps also can prevent sedimentation in ecologically sensitive areas vulnerable to the effects of sedimentation or sediment-associated contaminants.

Hydrodynamic conditions, rate of settling, composition of settled material, and chemical constituent levels are important components for evaluating whether a sediment trap can effectively capture sediment and, thus, reduce downstream sediment transport and river maintenance requirements. During the 16-month field investigation, these parameters were measured in the Saginaw River; results are discussed in this report.

1.2 Project Overview

The following two studies were developed by the Technical Workgroup:

- Study #1 involved the coring and fractionation of sediments at the Ojibway Island turning basin (OTB), located in the former navigational channel of the Upper Saginaw River, approximately 3 miles south of the confluence of the Tittabawassee and Shiawassee Rivers. Figure 1-1 shows the location of the OTB. The OTB had not been dredged for approximately 20 years (Ostaszewski 2006), since the terminus of navigation was moved downstream to the SSTB (located at river mile (RM) 17.5).

- Study #2 evaluated sediment trap performance and feasibility at the SSTB. USACE removed approximately 89,759 cubic yards (CY) of sediment from SSTB during emergency maintenance work conducted in August–September 2006 (Mundell 2008). The SSTB is located in the navigational

[1] The Technical Workgroup includes Dow, Michigan Department of Environmental Quality (MDEQ), USACE, Michigan Department of Natural Resources (MDNR), Department of Interior, U.S. Fish and Wildlife Service (USFWS), and the Saginaw Chippewa Indian Tribe.

channel of the Upper Saginaw River, approximately 5 miles south of the confluence of the Tittabawassee and Shiawassee rivers at RM 17.5 (Figure 1-1).

The studies were conducted between October 2006–December 2007 in accordance with the following work plans prepared by ENVIRON International Corporation (ENVIRON) on behalf of Dow and approved by the Technical Workgroup:

- *Characterization of Sediment in the Ojibway Turning Basin, Field Sampling and Analysis Plan*, submitted to the ADR Facilitator by ENVIRON on October 16, 2006
- *Sediment Trap Field performance and Feasibility Study in the Saginaw River Sixth Street Turning Basin, Sampling and Analysis Plan*, submitted to the ADR Facilitator by ENVIRON on October 3, 2006

The field and supporting laboratory work was designed to assess the feasibility of using sediment traps to collect sediments under a range of hydrodynamic conditions in the Saginaw River. Specific goals of these investigations included:

- Develop and evaluate a suite of state-of-the-art tools for characterization of the performance and efficacy of a sediment trap.
- Establish a suspended sediment mass balance across the SSTB to estimate baseline (current conditions) sediment and contaminant mass deposition in the traps over time and under varying flow regimes.
- Assess the current and potential capacity of the SSTB to capture and remove sufficient sediment to reduce downstream USACE maintenance dredging requirements.
- Develop a set of data supporting a modeling framework to allow for the evaluation of long-term sediment trap performance, operation, and maintenance.
- Evaluate the current and potential capacity of the SSTB sediment trap to capture and remove contaminated suspended sediments from the Saginaw River.

1.3 Study #1 Scope and Objectives

Study #1 characterized polychlorinated dibenzo-p-dioxins (PCDDs) and furans (PCDFs) (PCDD/F) concentrations in historical sediment deposits at the OTB and correlated the distribution of congeners at different depths (to the extent possible) with physical or chemical sediment characteristics, such as particle size distribution (PSD), total organic carbon (TOC), black carbon (BC) content, and bulk density. This study supplemented ongoing investigations measuring PCDD/F concentrations associated with different morphological features (e.g., levees, wetlands, floodplain soils, and river terraces) to better understand the distribution of PCDD/F in soil and sediment samples and to determine possible relationships between PCDD/F concentrations and sediment physical characteristics.

The study was conducted in two phases. Phase 1 included sediment coring, vertical segmenting of sediment cores, analysis of bulk PCDD/F concentrations, and analyses of bulk PSD, TOC, BC, and mineralogy. Phase 2 included sediment fractionation studies using a subset of the bulk samples. PCDD/F fractionation protocols developed by Dow's Environmental Chemistry group were applied to a subset of sediment samples collected during Phase 1. The fractionation analytical approach is currently under development by Dow using floodplain soil samples, and is described in Appendix G of the *Geomorph® Sampling and Analysis Plan* (ATS 2006). The approach involved fractionating samples into sand- (53–2000 µm), silt- (5–53 µm), and clay- (<5 µm) size fractions and analyzing those fractions for PCDD/F, TOC, and BC.

At the time the work was initiated in the fall of 2006, the following scope was identified for Study #1 (ENVIRON 2006a):

- Collection of empirical data on the distribution and capture of PCDD/F in historically deposited sediments at OTB to understand depositing and layering characteristics (e.g., size of particles and mass of constituents).
- Assessment of how furan and dioxin congener distributions and dioxin toxic equivalence (TEQ) concentrations in sediment deposits may have changed over the past 20 years in the vertical sediment profiles from the OTB cores.
- Characterization of the morphological distribution of deposited sediments, including grain size and organic carbon content, and a comparison of these morphological characteristics with furan and dioxin TEQ levels.
- Application of PCDD/F fractionation methods to river sediments by Dow's Environmental Chemistry Group to better understand PCDD/F distribution based on sediment grain size and sediment morphology.

1.4 Study #2 Scope of Objectives

Study #2 was conducted at the SSTB, which underwent limited emergency dredging in August–September 2006. The study examined sedimentation processes, and employed a mass balance approach, measurement of bedload and gross sediment deposition using field-deployed sediment trap sampling units, and bathymetry to quantify the net sediment deposition in the SSTB under varying hydraulic flow conditions.

The mass balance study involved measuring river transport velocities, cross-sectional areas, suspended solid loads, and PCDD/F concentrations in suspended solids under a variety of flow conditions through different seasons. Sediment transport behavior within the SSTB was investigated and sediment removal (erosion) and settling were quantified to determine the effectiveness of the SSTB as a sediment trap—specifically, its effectiveness in capturing sediments and associated contamination.

The Sediment Mass Balance Study Conceptual Model (Figure 1-2) shows that as upstream sediment mass is transported into the SSTB, a portion is lost due to particle settling, and the remaining sediment mass is transported downstream (out of the SSTB). Mass equals the volumetric flow rate of water multiplied by the concentration of sediment. To determine the amount of sediment removed by the SSTB, mass into the system was measured at the upstream transect and mass out of the system was measured at the downstream transect. The difference between these two measurements represents the amount of sediment removed.

At the time the work was initiated in the fall of 2006, the following scope was identified to facilitate determining the feasibility of the SSTB as a sediment trap (ENVIRON 2006b):

- Quantification of net sediment deposition in the SSTB sediment trap.
- Measurement of net TEQ mass deposition in the SSTB sediment trap.
- Assessment of the performance of a dredged turning basin regarding the capture and entrapment of suspended solids and TEQ mass.
- Measurement of sediment and TEQ mass entering and exiting sediment trap sampling units installed in the SSTB.
- Collection of data to facilitate the implementation of an effective sediment trap for long-term river maintenance and source control.

1.5 Monitoring-Event Flow Conditions

Field monitoring activities described in this report were structured around a series of targeted flow conditions related to varying hydrodynamic weather events. Target conditions for monitoring included:

1. Dry-weather, low-flow conditions
2. Small rain, medium-flow conditions
3. Wet-weather, high-flow conditions

Actual monitored events occurred as follows:

- Event #1: November 13–28, 2006, Medium-Flow event. This event was originally targeted as a dry-weather monitoring event, but rainfall during the monitoring period increased flow to a moderate level. The peak flow rate was measured as 7,560 cubic feet per second (cfs), well below a 1-year-recurrence-interval event but greater than the dry-weather event (Event #3).
- Event #2: March 23–28, 2007, High-Flow Event. The March 2007 monitoring event occurred in response to significant rainfall in the Tittabawassee and Saginaw River that coincided with thawing of frozen ground and snow melt, resulting in elevated flows on the Saginaw River. The peak flow rate was approximately 23,900 cfs, corresponding to a 1-year-recurrence-interval event on the Saginaw River. The corresponding flow on the Tittabawassee River upstream was approximately a 3-year-recurrence-interval event.
- Event #3: July 9–11, 2007, Low-Flow Event. Monitoring was conducted during a midsummer dry period, with measured flows ranging from -1,810 (reversal) to 2,260 cfs. No rainfall was recorded during this event.

1.6 Document Organization

This report is organized as follows:

- Section 1.0: Introduction
- Section 2.0: Project Background
- Section 3.0: Field Procedures
- Section 4.0: Study Results
- Section 5.0: Summary and Conclusions
- Section 6.0: References

2 Project Background

2.1 Site Description

Historical studies conducted by Dow, MDEQ, and USACE in the Saginaw River identified elevated concentrations of PCDD/F in the sediments of the upper Saginaw River, primarily in the non-navigational portion of the river from of the confluence of the Tittabawassee and Shiawassee rivers (Green Point) to the SSTB (Figure 1-1). In this area of the upper Saginaw River, two navigational turning basins exist: the OTB and the SSTB. The OTB is located 3 miles north of Green Point, at RM 19.2 (USACE 1986). It was originally excavated bank-to-bank to create a surface area of 600 x 650 feet (ft) but has silted in since the last time it was dredged more than 20 years ago (Ostaszewski 2006). This turning basin currently contains an estimated 75,000 CYs of sediment. The SSTB, approximately 5 miles downstream of the confluence of the Tittabawassee and Shiawassee rivers (RM 17.5), is the current terminus of commercial navigational dredging, and was dredged of approximately 89,759 CY of sediment during emergency maintenance work conducted in August–September 2006 (Mundell 2008). Maintenance dredging of the SSTB is scheduled to occur every two to three years to a bed elevation of 557.5 ft, which is approximately 20 ft below the typical Saginaw River water level. The OTB and SSTB lie within a portion of the Saginaw River located in Saginaw, Saginaw County, in Michigan's Lower Peninsula. The Saginaw River, part of the Saginaw River Watershed, contains four major tributaries: the Cass River, Flint River, Shiawassee River, and Tittabawassee River. The Saginaw River flows northeast and drains directly into Saginaw Bay (USEPA 1995).

2.2 Site Geology

Michigan is composed of two geographic sections, the Upper Peninsula and the Lower Peninsula. Similarly, Michigan's geology is characterized by two distinct rock groupings. The western portion of the Upper Peninsula is composed of Precambrian bedrock of the Canadian Shield, while the eastern portion of the Upper Peninsula and the entire Lower Peninsula are composed of Paleozoic and Mesozoic sedimentary rocks of the Cambrian and Jurassic ages (MDEQ 2003). This latter bedrock grouping comprises the Michigan Basin.

The Michigan Basin stretches across the eastern portion of Michigan's Upper Peninsula and its entire Lower Peninsula into Illinois, Ohio, Indiana, Wisconsin, and Ontario, Canada (USGS 2000). This basin "subsided rapidly from Cambrian to Silurian time as it filled with shallow-water marine sediments" (USGS 2000). Glacial movement into and out of the basin resulted in the Pleistocene-era deposition of unconsolidated tills, gravels, sands, silts, and clay over much of the basin's bedrock in Michigan.

Both the OTB and the SSTB are underlain by the Saginaw Formation (MDNR 2001). This formation—deposited during the Pennsylvanian period—is composed primarily of sandstone, shale, shaley limestone, and occasional coal beds (MDEQ 2000). Surficial materials deposited during the Quarternary period—via glacial advance and retreat—include lacustrine clay and silt and lacustrine sand and gravel.

2.3 History of Dredging and Dredge Disposal on the Saginaw River

Although dredging was conducted in the Saginaw River in the 19th century to clear sand bars and facilitate transportation (PLS 2000), the first federal authorization to dredge and maintain a navigational channel through Saginaw Bay and Saginaw River occurred in 1910 (USACE 2004). The original channel was 200 ft wide and was authorized to be 18.5 ft deep in the Saginaw Bay and 16.5 ft deep in Saginaw River. In 1930, the navigational channel was deepened to 18.5 ft and extended from Saginaw Bay to the City of Saginaw. Dredging of a wider and deeper channel in Saginaw Bay was authorized in 1954 along with further deepening of the Saginaw River's navigational channel and the Essexville and Carrollton turning basins. In 1962, Congress approved further deepening of the Saginaw Bay and Saginaw River navigational channels and the construction of two additional turning basins. Three years later, authorization was granted to dredge the river's navigational channel downstream of the New York Central railroad bridge in Bay City to its current depth of 25 ft (USACE 2004).

USACE maintains the navigation channel in the Saginaw River from the City of Saginaw to the mouth of the river and for another 14-miles into Saginaw Bay. In order to most efficiently manage dredged materials from the river and bay, USACE has divided the river and bay into two reaches (USACE 2004). The upper Saginaw River extends downstream from the confluence of the Tittabawassee and Shiawassee rivers in Saginaw to RM 4.7 in Bay City. The lower Saginaw River extends from RM 4.7 to the mouth of the river and for 14 miles into Saginaw Bay. Regular maintenance of the upper Saginaw River channel has not occurred since the early 1990s because there is no active dredge material disposal facility (DMDF) for this reach (USACE 2004). The lower Saginaw River is maintained at depths of 25 ft or greater and dredged material is disposed of at the Saginaw Bay confined disposal facility (CDF) located on Channel and Shelter Island in Saginaw Bay, approximately 2 miles from the mouth of the Saginaw River.

2.3.1 Lower Saginaw River Navigation Dredging

USACE maintains the navigation channel of the lower Saginaw River from RM 4.7 to RM 1 at a depth of 25 ft, RM 1 to RM 0 at 26 ft, and the 14-mile channel in Saginaw Bay at 27 ft. According to recently available data from USACE, maintenance dredging has occurred throughout the lower Saginaw River every one to two years since 1993 (Figures 2-1a and 2-1b) (ENVIRON 2007). Approximate sediment volumes removed annually from the entire Saginaw River since 1963 are shown in Figure 2-2. On average, USACE estimates that maintaining the lower Saginaw River channel at target depths requires removal of 100,000 to 150,000 CYs of sediment annually (USACE 2007a).

2.3.2 Upper Saginaw River Navigation Dredging

Portions of the upper Saginaw were dredged in 1992 and 1995 (Figures 2-1c and 2-1d) on an emergency basis (USACE 2004), but the channel has not been regularly maintained at its target depth of up to 22 ft for more than 20 years. Between 1995 and 2006, accumulated sediment created shallow areas that required cargo ships to unload portions of their cargo at downstream docks before continuing upstream to Saginaw (USACE 2004). In 2006, several ships ran aground in the SSTB, prompting USACE to conduct emergency dredging. USACE removed 89,759 CY of sediment from the SSTB; dredged material was transported to the Saginaw Bay CDF. Maintenance dredging of the upper Saginaw River navigation channel and turning basins is scheduled to occur every two to three years. The SSTB will be dredged to a bed elevation of 557.5 ft, which is approximately 20 ft below the typical surface water elevation.

2.3.3 Remediation Dredging

The lower Saginaw River was the subject of a 1998 consent decree signed by the MDEQ, the Michigan Attorney General, the U.S. departments of Interior and Justice, the Saginaw Chippewa Indian Tribe, General Motors Corporation, and the cities of Saginaw and Bay City. Provisions of the consent decree included a sediment removal component from the Saginaw River. Dredging began in April 2000 and finished in July 2001. Removed sediments were disposed of at Saginaw Bay CDF (USFWS 2007).

2.3.4 Dredged Material Disposal Facilities

Until 1969, dredge materials from the creation and maintenance of the navigation channel in the river and bay were disposed of in open water (USACE 2004). However, the federal River and Harbor Act of 1970 required dredged materials from contaminated areas to be disposed in diked areas or CDFs. Bay City constructed the Skull Island CDF at RM 8.3 in 1969 to accept dredge materials from the upper and lower Saginaw River. Within two years, the Skull Island CDF reached its capacity. Bay City subsequently constructed the Middle Ground Island CDF at RM 7.0 in 1972 and it accepted dredged material from the upper Saginaw River from 1973 until it reached capacity in 1984.

USACE started identifying potential locations for a high-capacity DMDF for the lower Saginaw in the 1960s (USACE 1974). Two artificial islands (Channel Island and Shelter Island), created by previous dredging in Saginaw Bay, were selected (USACE 1974). The Saginaw Bay CDF was completed and opened to receive dredged sediment in 1977 (USACE 2004). The CDF approached its original capacity in 1995, prompting USACE to extend its life by raising the CDF dikes. Recently, USACE estimated that the Saginaw Bay CDF has insufficient capacity to receive dredged material from the lower Saginaw River channel beyond approximately 2032 (USACE 2007a). USACE's estimates assumed that the CDF would only accept dredge materials from the lower Saginaw River; moreover, USACE determined that it is not cost-effective to ship dredged materials from the upper Saginaw to the Saginaw Bay CDF (USACE 2004).

Since the closure of the Middle Ground Island CDF in 1984, USACE has had no place to dispose of dredged material from the upper Saginaw; however, sediments from the 2006 emergency dredging of the upper river were disposed of at the Saginaw Bay CDF (USACE 2004). Currently, work is underway by USACE to construct a DMDF on 281 acres in portions of Saginaw and Bay Counties. The DMDF is intended for permanent storage of sediments dredged from the navigation channel in the Saginaw River, including the Carrollton and Airport turning basins, and sediment from future maintenance dredging of the SSTB.

2.4 Existing Large-Scale Sediment Traps

Many existing sediment traps were originally constructed as channels or turning basins to accommodate shipping needs, without regard for their function as sediment traps. For example, at the Fox River, a navigational channel was found to serve as a sediment trap for polychlorinated biphenyl (PCB)-

contaminated sediments originating upstream (Appleton 2001). The efficacy of the channel as a sediment trap is maintained by periodic dredging. Other traps constructed for the purpose of collecting sediment in a convenient location to reduce dredging costs include:

- At Savannah Harbor (Lockwood Green Associates 2007), a large sediment trap was constructed in the lower Back River. Of the sediment volumes dredged annually from the harbor, 40% are extracted from the sediment basin, which allows for less extensive dredging and maintenance, reducing annual costs. An evaluation of the potential impact of deepening the trap on sediment volumes and dredging costs is ongoing.

- In the Mississippi River (Louisiana Coastal Wetlands Conservation and Restoration Task Force 2007), a sediment trap concentrates sediment deposition to facilitate its collection for marsh restoration activities.

- Based on evidence from sediment cores, a sand trap at the Channel Islands Harbor (Hobson 1982, cited in Parchure 2002) has been found to collect the bulk of littoral drift sediment.

- Sediment traps at three riverine inflows to estuaries connected to the Baltic Sea were studied. The traps were designed to collect sediments containing phosphorus, which contribute to eutrophication. Two of the traps were constructed at the river mouths, and one in the lock-impounded section of its river. All three traps are effective at trapping sand, larger particles, and associated phosphorus. Mass balance calculations determined that the two traps located at the river mouths captured 11% and 20% of the total sediment load, and 15% and 11% of the phosphorus load, respectively. The trap in the impounded area captured 3% of the total sediment load and 3% of the phosphorus load.

- An assessment of sediment traps along the Saginaw River, Michigan was conducted by the USACE using numerical models and theoretical analysis (USACE 2001).

3 Field Procedures

Field procedures for Studies #1 and #2 are discussed in this section and include:

- Geophysical surveys, including bathymetric surveys and side scan sonar surveys.
- OTB sampling activities, including sediment coring, core processing, and sample analyses.
- SSTB sampling activities, including the collection of hydrodynamic, suspended solids, and sediment transport data; and analytical methods.

Photographs of the field are included in Appendix A.

3.1 Geophysical Surveys

Ocean Surveys Inc. (OSI) (Old Saybrook, Connecticut) conducted bathymetric and side scan sonar surveys in the vicinity of the OTB and SSTB (Figure 3-1) to meet the following objectives:

- Establish an accurate and current representation of the depth and morphology of the river bottom relative to known horizontal and vertical data.
- Assemble bathymetric information for input to the sediment transport study.
- Develop a baseline for potential future bathymetric surveys.
- Identify depositional areas by comparing bathymetric surveys over time (~ 1 year).

3.1.1 Bathymetric Surveys

During each survey, full river bottom coverage was achieved utilizing a Reson Seabat 8125 ultra-high-resolution multibeam echosounder and an Applanix POS-MV V4 inertial navigation/motion compensation system fitted with Trimble RTK GPS receivers. Both instruments, along with Seabird Electronics sound velocity measuring devices were interfaced to the Coastal Oceanographic’s HYPACK (HYPACK) navigation and data logging system. The highly accurate real time kinematic (RTK) Global Positioning System (GPS) system is capable of 1-centimeter (cm)-horizontal and 2-cm-vertical precision. The system consists of a base station unit placed at a known position, which communicates with the vessel system to provide the necessary corrections to satellite readings. The bathymetric survey team operated under the direction of an American Congress on Surveying and Mapping (ACSM) -certified hydrographer. The field team attempted to collect bank-to-bank soundings; however, due to shallow areas of the Saginaw River shoreline and the presence of shoreline obstructions, bank-to-bank coverage was not always possible.

A comparison was performed between the multibeam hydrographic surveys of the SSTB conducted in November of 2006 and September of 2007. Difference elevation (2007 minus 2006) values were generated using the HYPACK MAX “TIN Model” program. These difference data were saved in a 1 ft x 1 ft bin format and contoured for presentation. The 2007 and 2006 TIN surfaces were developed from

1-ft-by-1-ft data bins of each full dataset, with the average elevation within each one-ft-square cell posted at the center of the cell. Volume calculations were made using the HYPACK "TIN to TIN" comparison method.

3.1.2 Side Scan Sonar Surveys

Side scan sonar was used to map river bottom morphology and surface sediment distribution, and to identify objects resting on the riverbed. Data were obtained using a Klein 3000 Dual Frequency Side Scan Sonar. Positioning of the survey vessel was achieved through RTK GPS. Geodetic data were output to the HYPACK MAX software. Side scan imagery was collected along multiple survey transects parallel to the shoreline, spaced at 60-ft nominal intervals with a range scale of 25 meters in the OTB and SSTB.

3.2 Ojibway Turning Basin Sampling Activities

OTB sampling activities included sediment coring; core processing; and analysis of sediment core samples for PCDD/F TEQ levels, PSD, TOC, BC, moisture content, and bulk density.

3.2.1 Sediment Core Collection and Processing

Sediment cores were collected from eight locations in the OTB, between November 29-December 2, 2006. The eight coring locations are shown on Figure 3-2. Specific sediment core locations were field-selected and exact coordinates were recorded from an onboard digital GPS. The horizontal positions of sediment core locations were referenced to Michigan State Plane Coordinate System, South Zone (NAVD 83). The cores were completed to a nominal depth of 20-ft using vibracoring methods. To obtain the necessary sediment volume for sample analysis and archiving, three cores were advanced at each location for a total of 24 cores. Table 3-1 summarizes the various cores collected, including depths of penetration and recovery for each location. Sediment core boring logs are presented in Appendix B.

Based on a review of core lithology, five samples from each core location were designated for laboratory analyses (totaling 40 samples); remaining samples were archived. Each sediment sample had a maximum depth interval of 6 inches. In some cases, sample intervals were smaller to avoid mixing different lithologies in a single sample. Sediment samples were analyzed for PCDD/F concentrations, PSD, TOC, BC, moisture content, and bulk density. Replicate sediment samples were collected for Quality Assurance/Quality Control (QA/QC) purposes. Laboratory analytical reports are presented in Appendix C. In addition to the work summarized above, a study was conducted using sediment samples from OTB that were fractionated into different particle size subfractions. The fractionation study is presented in Appendix D.

3.2.2 Dioxins/Furans

Forty-three sediment samples were analyzed by Vista Analytical Laboratory, formerly Alta Analytical Laboratory (El Dorado Hills, California), using United States Environmental Protection Agency (USEPA) Method 1613, Revision B developed for isomer-specific determination of the 2,3,7,8-substituted, tetra-through octa-chlorinated, dibenzo-p-dioxins (PCDD) and dibenzofurans (PCDF) in aqueous, solid, and tissue matrices by isotope dilution, high-resolution capillary column gas chromatography (HRGC), and high-resolution mass spectrometry (HRMS). In this method, the analytes are separated by the HRGC and detected by a high-resolution mass spectrometer. An individual 2,3,7,8-substituted congener is identified by comparing the HRGC retention time and ion-abundance ratio with the corresponding retention time of an authentic standard and the theoretical ion-abundance ratios. An initial calibration curve is analyzed to demonstrate the linearity of the HRMS system over the calibration range and verified with a continuing calibration verification standard per analytical batch. Quantitative analysis is performed using selected ion current profile areas. Detection limits are sample-specific and congener-specific and are based on the signal-to-noise ratio.

Results were reported in nanogram per kilogram (ng/kg) dry weight to a limit of 1.0 ng per congener. Individual congener concentrations were multiplied by 2005 World Health Organization (WHO) toxic equivalency factors (TEF) to calculate TEQ as 2,3,7,8-Tetrachlorodibenzodioxin (TCDD). TEQs are reported in ng/kg, or part per trillion (ppt). Positive congener results were treated conservatively and rounded up. Where at least one positive congener was reported, other non-detect values were entered at one-half of their respective reporting limit and the aggregate TEQ was flagged as estimated.

3.2.3 Physical Analyses

Sediment samples were analyzed for geophysical parameters including PSD, bulk density, TOC, and BC. Forty-three samples were analyzed for PSD by A & L Analytical Laboratories, Inc. (Memphis, Tennessee) using ASTM D422 (+250 µm sieving). A&L Analytical Laboratories, Inc. also analyzed 40 sediment samples for both bulk density (using ASTM D2937) and moisture content (using ASTM Method D2216). Forty-three sediment samples were analyzed for TOC and BC by Quantitative Technologies, Inc. (QTI) (Whitehouse, New Jersey) using standard method ATP 30-18 developed by QTI and Dow.

3.3 Sixth Street Turning Basin Sampling Activities

For each flow event (Low-Flow, Medium-Flow, and High-Flow), sampling was conducted along two transects upstream and downstream of the SSTB, and three transects located within the SSTB (Figure 3-3). The primary goal of the surveys was to collect the data necessary to implement a mass balance evaluation by measuring river transport velocities, suspended solids loads, and TEQ levels on the suspended solids, and to gather information related to bedload sediment transport and deposition.

3.3.1 Event-Based Hydrodynamic Data Collection

Velocity monitoring at designated river transects (upstream, downstream, and within the SSTB) was conducted using a boat-mounted RD Instruments 1,200 kHz Acoustic Doppler Current Profiler (ADCP). The survey team piloted the survey vessel across the river while at the same time collecting current velocity profiles of the water column. Current velocity data were compiled with a vertical resolution of 0.5 meters and a horizontal resolution of 5 meters. Each transect was traversed four times consecutively to complete an individual velocity profile.

3.3.2 Surface Water Elevations

Surface water elevations were monitored during the November 2006 Medium-Flow event (November 6 through December 4) using an in-situ pressure sensor located at the Genessee Road Bridge (Figure 3-3) crossing, just upstream of the study area, and set to record data every 15 minutes. The November 2006 surface water elevation was referenced to the International Great Lakes Datum (IGLD 85) and surveyed to a vertical reference point on the Genessee Road Bridge.

In March 2007, a radar level transmitter was installed on the Genessee Road Bridge. This device has an advantage over the pressure sensor installed in November 2006 because it provides noncontact measurement and is unaffected by water conditions or floating objects. It measures distance to the water surface from above the water surface, by emitting a short electromagnetic pulse. When the return signal is received, the distance is calculated and converted to elevation.

The radar assembly includes a data logger, solar panel, and battery. The entire system was housed in a protective aluminum enclosure, mounted to the Genessee Road Bridge railings with brackets and located over the water. The instrument was configured to collect data at 15-minute intervals. Access for data download was via the pedestrian walkway.

3.3.3 Turbidity and Particle Size Distribution Sampling

Concurrent with ADCP profiling, the survey team collected in-situ PSD and turbidity profiles of the river. This was accomplished by using an optical back scatter (OBS) meter to measure turbidity and suspended sediment concentrations (SSC) and a Laser In-Situ Scattering and Transmissometry (LISST-100) to measure in-situ PSD. General water quality parameters (pH, dissolved oxygen, temperature, and conductivity) were measured using a SeaBird SBE 19plus SeaCat Conductivity-Temperature-Depth profiler during the November 2006 Medium-Flow event and a Hydrolab datasonde at approximately 2-3-ft intervals over the water column during the March 2007 and July 2007 sampling events.

The profiles were repeated in parallel with ADCP profiling, twice per day at the upstream and downstream transects, to document spatial variations in temperature, density, turbidity, and PSD, and to determine relationships between these characteristics. During the March 2007 High-Flow event, a profile was added in the middle of the SSTB.

3.3.4 Surface Water Grab and Composite Samplers

During all three events, unfiltered river water samples were collected to measure suspended solids, suspended sediment, and TOC concentrations concurrently with turbidity using the OBS and LISST-100 equipment. At each water sampling transect, composite samples were collected using depth-integrated equal-discharge-increment (EDI) methods. Each sample was composited from equal water volumes obtained from three sampling stations across each transect, representing EDIs across the river, to ensure optimal representation of each transect.

River water samples were tested in the laboratory to determine:

- Total suspended solids (TSS), using Method 160.2.

- SSC, using Method ASTM D3977-97.
- PSD, using a laser diffraction method (November 2006 event only).
- TEQ levels on suspended solids (5-gallon samples collected and filtered at the lab), using Method 1613B.
- TOC, using USEPA Method 9060A.

Suspended solids measurements for the Saginaw River were obtained by several methods. These methods included collecting composite and discrete water samples for laboratory analyses of TSS and SSC,[2] and collecting discrete- and continuous-depth-interval OBS data, which were converted to TSS concentrations via instrument-specific calibrations.

Composite TSS and SSC measurements were determined at each of three stations (East, Center, and West channel) across the two river transects (Upstream and Downstream). The East, Center, and West channel water samples then were poured into a single bottle to produce a composite sample for each transect. During the November 2006 Medium-Flow and July 2007 Low-Flow events, samples were collected from each transect during the morning and afternoon for three days. Samples were collected from each transect once per day for the July 2007 Low-Flow and November 2006 Medium-Flow events. During the March 2007 High-Flow event, samples were collected with automatic samplers located upstream and downstream of the SSTB (Figure 3-3). These samples were analyzed for TSS, SSC, and TOC. Samples were collected every hour from March 23 (the first day of the event) until March 30. The hourly samples were composited over two-hour periods for the first 24 hours of the sampling event, prior to sending the samples to the lab. The hourly samples collected from March 24–March 30 were composited over four-hour periods.

Continuous OBS depth profiling was conducted during the March and July 2007 events to provide datasets that correspond to the lowering and raising of the OBS probe through the water column at each sample station. OBS water column measurements required calibration using site-specific suspended solids measurements (Appendix E). Discrete water samples were collected in July 2007 at the Upstream and Downstream East channel stations by attaching tubing from a peristaltic pump to the OBS probe. The continuous OBS profiling was paused at discrete depths to run the pump and collect water samples into separate sample bottles for each depth interval.

3.3.5 Long-Term Hydrodynamic and Suspended Solids Data Collection

A long-term hydrodynamic survey was conducted from May-December 2007. The objective of the long-term survey was to provide information on flow and solids variability over time, particularly spring/summer variability in sediment load and transport characteristics. Instrumentation was placed in the river to monitor velocity and suspended solids over approximately six months, accounting for spring high-flow conditions and subsequent flow reductions as well as transitional conditions.

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[2] SSC is a modification of TSS. The methods differ primarily in their preparation. American Society for Testing Materials (ASTM) TSS Methods stirs and collects the sub-sample using a pipette to draw from the whole sample container. The ASTM SSC Method uses the whole sample, and is considered to achieve complete capture of the suspended sediment.

The monitoring equipment was installed on wooden pilings, just downstream of the Genessee Road Bridge (see Figure 3-3). Photographs of the installation are included in Appendix A. The velocity measurements were collected using side-looking ADCP, which provide average channel velocities by measuring a broad spectrum of current velocities across the width of the channel. In-situ TSS concentrations and turbidity were measured using an OBS meter. In-situ PSD was measured using a LISST-100. The three instruments were set to record data at 15-minute intervals.

Originally, the instruments were positioned in the center of the water column. However, very little change in flow velocities and solids transport was observed in the center of the water column during the July 2007 Low-Flow event. For this reason, and because results from the November 2006 event indicated that bedload transport plays a significant role in the transport of solids in the Saginaw River, the OBS and LISST-100 instruments were moved in August to measure solids transport at the bottom of the water column.

3.3.6 Sediment Bedload and Sediment Trap Sampling

Sediment bedload samples were collected during all three sampling events, using a Helley-Smith bedload sampler deployed from a moored boat. Photographs of the bedload sampling are included in Appendix A. Bedload was monitored at each of the three sampling locations along the upstream and downstream transects to provide estimates of near-bed sediment characteristics upstream and downstream of the SSTB (Figure 3-3).

During the November 2006 Medium-Flow event, the bedload samplers were deployed on the upstream transect in the morning for approximately four hours and then moved to the downstream locations at midday, where they were deployed for approximately four additional hours.

During the March 2007 High-Flow and July 2007 Low-Flow events, bedload samplers were deployed at all six sampling locations—upstream and downstream in succession—left in place for approximately six hours, and then retrieved in order of deployment. Due to the small amount of bedload observed in July 2007, bedload samples from all three sampling days were composited to generate sufficient material for analysis of TEQs.

Sediment trap sampling units were deployed at the riverbed sediment surface. These sampling instruments measure the quantity of settling particulate material (suspended solids) in aquatic systems. The sediment trap sampling units consisted of upward-facing funnels with 2.5-inch-diameter trap openings, mounted flush with the sediment surface to direct settling sediment towards an arrangement of baffles for collection. A total of 15 sampling units were deployed at three locations within the SSTB transects and at three locations along the upstream and downstream transects during each of the November 2006 Medium-Flow and July 2007 Low-Flow events (Figure 3-3). The deployed traps provided a measurement of gross sedimentation rate at each location, representing conditions upstream of the SSTB; the leading, middle, and trailing end of the SSTB; and downstream of the SSTB.

The sediment trap sampling units were deployed flush with the sediment bed, to provide an accurate and representative measurement of the gross deposition rate collected at the sediment-water interface. During the November 2006 Medium-Flow event, 15 sampling units were deployed for 12 days; however, a rain event caused most of the traps to overfill and three units could not be located, so only 12 were retrieved.

During the July 2007 Low-Flow event, 15 sampling units were deployed for seven days. All 15 were retrieved. Samples from the units were submitted to the laboratory for analysis of TEQs.

4 Study Results

4.1 Geophysical Survey Results

Multibeam bathymetric and side scan sonar surveys were performed in November 2006 (Figure 3-1). A fine-grid multibeam survey of the OTB and SSTB provided the data required for detailed mapping of river morphology. Following the multibeam survey, images of the river bed were created using side scan sonar to detect and identify bedforms and underwater objects.

4.1.1 Ojibway Turning Basin Bathymetric Profiles

The OTB dimensions are approximately 660 ft across at the upstream (southwestern) end and approximately 600 ft across at the downstream (northeastern) end of the turning basin and approximately 700 ft wide. Bathymetric contours indicate outside banks (southeast edge) have slopes of approximately 20–27% and inside banks (northwest edge) have slopes of approximately 4–6%. Water depth ranges from the waterline (elevation 577 ft) to approximately 18 ft below the waterline (elevation 559 ft) (Figure 4-1).

At the upstream side, the river channel ranges in depth from approximately 12–15 ft below the waterline (elevation 565–562 ft), and accounts for approximately 340 ft of the width of the OTB (52%). At the downstream side, channel depth increases to 18 ft below the waterline (elevation 559 ft) while the width of the channel decreases to approximately 185 ft (30% of the width of the OTB). The deepest part of the river channel (thalweg) appears to cross over just upstream of the OTB.

4.1.2 Sixth Street Turning Basin Bathymetric Profiles

The SSTB is approximately 400 ft across at the upstream (southern) end and approximately 370 ft across at the downstream (northern) end, 700 ft across at the center and approximately 975 ft wide (Figure 4-2). Bathymetric contours indicate the outside banks at the western edge have slopes of approximately 16–30%, and inside banks at the northwest edge have slopes of approximately 7–50%. Water depth ranges from the waterline (elevation 577 ft) to approximately 28 ft below the waterline (elevation 549 ft).

At the upstream side, the river channel ranges in depth from approximately 16 ft below the waterline (elevation 561 ft) in the unmentioned channel to approximately 21 ft below the waterline (elevation 556 ft) in the actively maintained navigation channel or dredged area, indicating a 5-ft elevation difference following the 2006 maintenance dredging event. At the downstream side, the channel depth increases to 23 ft below the waterline (elevation 554 ft). The deepest part of the basin is approximately 28 ft below the waterline (elevation 549 ft). The navigation channel is maintained at the target depth of 20 ft (USACE 2007b) below the Low Water Datum (LWD). The LWD is recognized as the elevation of 577.5 ft above Mean Water Level, International Great Lakes Datum (I.G.L.D.), 1985 (USACE 2007c). At the current target depth of 20 ft (elevation 557 ft), the navigation channel width is approximately 180 ft.

4.1.3 Comparison of Bathymetric Surveys

To quantify sediment deposition in the SSTB, an integration of depth changes over bathymetric survey area from two different time periods (Figure 4-3) was calculated. Riverbed depth differences between the November 2006 and September 2007 surveys are presented in Figure 4-4. Within the SSTB, both scour and deposition were observed, as indicated by the blue and red areas (and intervening colors).

Figure 4-3 shows a deepening and broadening of the western side of the SSTB, forming a crescent of relatively uniform elevation (~545 ft) along its length. This apparent erosion area is likely due to ship propeller wash generated by vessels engaging in turning maneuvers. The bathymetric comparison suggests that deep scouring is largely confined to the west side.

Figure 4-4 shows a highly depositional area at the upstream (southern) end of the SSTB; specifically, approximately 10,130 CY of accumulated sediment, resulting in elevation changes of as much as ~7 ft. This approximately 2-acre section is proximal to the upstream extent of navigational dredging, and is upstream of the turning basin area commonly used by freighters.

Areas of lesser deposition and scour appear in the remainder (eastern side) of the SSTB, resulting in elevation changes of approximately ±2 ft. Key features of deposition and scour within the 34.4-acre SSTB include:

- 27,850 CY was deposited over a 15.7-acre portion of the SSTB.
- 25,100 CY of material was released from an 18.7-acre portion of the SSTB.
- Net deposition in the SSTB was approximately 2,750 CY.
- Within the 18.7-acre area, the “prop-scour arc” occupies approximately 3.6 acres and represents approximately 12,300 CY (~50%) of the released material.
- The upstream deposit area with up to 7 ft of deposition covers 2 acres with approximately 10,130 CY of material.

The 10,130-CY deposition is one of the most compelling lines of evidence supporting the efficacy of the SSTB as a sediment trap. Deposition in this area likely results from reduced surface water velocities caused by the widening of Saginaw River at its transition to the SSTB. Another contributing source of sediment may be freighters that could resuspend sediment into this area during turning maneuvers. Notably, the freighter traffic did not, in turn, disturb this deposit.

4.1.4 Side Scan Sonar Results

The most dominant features detected by side scan sonar in the OTB and SSTB were the sediment waves (moving sediment bed features); bridge piers; and the deepening of the river floor around the bridge piers, the outside river bends, and in the center of the SSTB (Figures 4-5 and 4-6). Other features identified in the side scan sonar images are rock or concrete rip-rap used for bank stabilization and bottom debris.

4.2 Study #1 – Ojibway Turning Basin Results

This section presents sediment TEQ results and lithologic characteristics and profiles at eight core locations in the OTB (Figure 3-2).

4.2.1 Sediment Core TEQ Profiles

Table 4-1 and Figure 4-7 show TEQ core profiles for the eight OTB sediment cores collected in November 2006. TEQ results ranged from 0.723–10,748 ppt with a median of 182 ppt. Vertical TEQ profiles in the OTB sediment cores reveal a depositional profile with higher TEQ levels in buried sediments and lower concentrations at the sediment surface. Natural deposition has led to decreasing surface sediment TEQ levels with time.

In Cores VC1 through VC7, surface sediment TEQ levels range from 55.5–630 ppt, with a median concentration of 287 ppt. At Core VC8, the surface sediment TEQ initially reported a concentration of 10,334 ppt. However, a replicate surface sediment sample collected from the 0-0.5 ft interval of VC8 had much lower TEQ of 16.9 ppt. A sample also was collected from the 0.5–1.0 ft interval to confirm the absence of elevated TEQ levels at Core VC8; the 0.5–1.0 ft interval had a TEQ level of 103 ppt. Notably, the VC8 surface sediment results, ranging from 16.9–10,334 ppt, reflect the typical heterogeneity of TEQ levels reported for the Saginaw River. Core VC8 resides near the deepest portion (the thalweg) of the river.

TEQ levels increased with sediment depth, reaching highest concentrations at between 4 and 10 ft below the sediment-water interface; in much deeper sediments, TEQ levels progressively decreased to below 10 ppt. Core VC7 revealed a buried TEQ sample greater than 10,000 ppt at the 6.0–6.5 ft depth interval. Buried TEQ deposits greater than 1,000 ppt were measured at sampling locations VC3, VC5, VC6, and VC7 at depth intervals approximately 6-10 ft below the sediment-water interface. Sediment TEQ levels progressively declined as the sediment surface was approached, reflecting the natural burial of elevated TEQ levels by sediments with lower TEQ levels. Because of the inclusion of deep samples below 10 ppt in the calculation of the overall median TEQ, the overall median value (182 ppt) is slightly lower than the median surficial value (287 ppt) reported above, despite the observed predominance of highest TEQ levels between 4 and 10 ft of depth.

4.2.2 Ojibway Turning Basin Geology

Figure 4-8a shows the locations of geologic cross sections illustrating the vertical and lateral extent of sediment strata in the OTB (Figures 4-8b-e). Figures 4-8b and 4-8c show cross sections that run generally perpendicular to river flow, from the northwestern bank towards the southeastern bank. Figures 4-8d and 4-8e show cross sections that generally run parallel to the flow of the river. Photographs showing the complete set of cores are included together with the boring logs in Appendix B.

Four distinct layers of sediment deposits, or strata, are evident within the sediment cores collected within the OTB, including:

- Gray to brown silt and clay with shells and organic material (OS I).

- Gray to brown sand with shells and organic material (OS II).
- Gray silty clay and sandy silt (G).
- Brown clay with trace gravel and cobbles (B).

Stratum OS I is typically represented by a dark gray to grayish brown clay, silt, and sandy silt with shells and black organic material. Stratum OS I was predominantly observed along the northwestern shoreline of the OTB, where it is approximately 13 ft thick, gradually decreasing in thickness towards the southeast where it becomes interbedded with Stratum OS II, then pinches out and is no longer present near the center of the river.

Stratum OS II is typically characterized by a dark gray to grayish brown very fine to fine sand with shells and black organic material. This stratum contains some thick interbeds of clay and silt. Along the northwestern shoreline, Stratum OS II was found in a thick layer below Stratum OS I. Towards the center of the river, Stratum OS II becomes interbedded with Stratum OS I. Stratum OS II thickness typically ranges from 1–5 ft in the OTB area.

Underlying strata OS I and OS II is Stratum G, typically represented by gray to very dark gray silty clay to sandy silt. This stratum consistently contains little to no gravel, organic material, or shells, and in some places, laminated with silt and fine sand. The base of this stratum grades with sand and gravel at some locations. Stratum G was found in each of the sediment cores collected from the shoreline to the center of the river and consistently observed at a mean sea level elevation of approximately 560 ft. Stratum G average thickness could not be determined as no bottom contact was identified in the majority of the borings.

One additional strata, B, was only identified at the base of the sediment core collected near the center of the river (core VC8). Stratum B is characterized by a brown to brownish gray clay with a trace to some rounded gravel and cobbles.

4.2.3 Ojibway Turning Basin Physical Sediment Characteristics

Samples were collected from the four strata encountered in the OTB and were analyzed for various sediment physical parameters including PSD, moisture content, bulk density, TOC, and BC (Table 4-2). Analytical laboratory reports for the physical testing results are included in Appendix C.

4.2.3.1 Sediment Particle Size Distribution

Sediment PSD was determined in 43 sediment samples, including field duplicates, from cores collected in the OTB. The following particle size ranges were quantified:

- Medium and Coarse Sand (0.25 millimeter (mm) – 2 mm)
- Fine Sand (0.05 mm – 0.25 mm)
- Silt (0.002 mm – 0.05 mm)

- Clay (<0.002 mm)

The PSD data indicate that stratum OS I consists primarily of fine sand (average 40%) and silt (average 39%), with some clay (average 15%) and some medium-to-coarse sand (average 6%), as well as scattered organic fragments. Stratum OS II consists primarily of medium-to-coarse sand (average 60%) and fine sand (average 29%), with lesser amounts of silt (average 8%) and clay (average 4%). Stratum G consists primarily of silt (average 44%) and fine sand (average 37%), with some clay (average 19%) and medium-to-coarse sand (average 6%). Stratum B consists primarily of fine sand (average 32%) and clay (average 30%), with lesser amounts of silt (24%) and medium-to-coarse sand (average 14%).

4.2.3.2 Moisture Content

For 40 sediment samples, moisture content ranged from 15%–132% (by mass), and averaged 52%. Stratum OS I typically had higher moisture content (average 85%) than other strata. Averages for strata OS II, G, and B were 32%, 52%, and 15%.

4.2.3.3 Bulk Density

Bulk density was measured in 40 sediment samples. The average bulk density measured for stratum OS I was 603 kilograms per cubic meter (kg/m3). Average bulk density measurements for strata OS II, G, and B were 1135 kg/m3, 910 kg/m3 and 1,484 kg/m3, respectively.

4.2.3.4 Total Organic Carbon

For 53 sediment samples—including field duplicates and lab replicates—TOC concentrations ranged from 0.05%–3.49%, and averaged 1.49%. The highest levels occurred in stratum OS I, which averaged approximately 2.47% TOC. Averages for strata OS II, G, and B were 0.45%, 1.13%, and 0.22%.

4.2.3.5 Black Carbon

For 53 sediment samples—including field duplicates and lab replicates—BC concentrations ranged from 0.05%–1.41%, and averaged 0.37%. The highest levels occurred in stratum OS I, which averaged approximately 0.52%. Averages for strata OS II, G, and B were 0.18%, 0.38%, and 0.05%.

4.2.3.6 Statistical Analysis of Total Organic Carbon and Black Carbon vs TEQ

Analytical PCDD/F TEQ, TOC, BC, and PSD results were evaluated using graphical and statistical methods to determine potential relationships between TEQ or TM17 (mass of the 17 dioxin/furan congeners with TEF values) and TOC, BC, and sample depth (Table 4-3). Depth profiles and grain size analyses are presented in Appendix F.

For each comparison, the Pearson's Correlation Coefficient and/or Spearman's rank correlation coefficient (Spearman Coefficient) was determined. The Pearson's Correlation Coefficient corresponds to the R2 associated with the best linear regression analyses. An R2 value of 1.0 indicates a perfect positive linear correlation. The Spearman Coefficient was used to evaluate the strength of any relationship between two sets of data (values close to either 1.0 or -1.0 suggest a stronger relationship).

The Spearman Coefficient differs from the R2 determined from the linear fit in that it does not presume the form of the relationship (e.g., linear or exponential).

The results of the evaluation (Table 4-4) are summarized below:

- TOC and BC percentages were analyzed against TM17 and TEQ values and their respective natural log values. The linear fit R2 values and Spearman's Coefficients do not suggest an association between TM17 and TEQ concentrations in the bulk sediment samples and TOC and BC percentages. Linear fit R2 values ranged from 0.26–0.51; corresponding Spearman coefficients ranged from 0.29-0.49.

- TOC and BC percentages and TM17 and TEQ concentrations were analyzed against percent grain size class, including sand, silt, and clay at their corresponding measured depths. A positive correlation between TOC and silt is suggested by the Spearman coefficient (0.60). Other relationships were not apparent.

- TOC and BC percentages were analyzed relative to depth interval. Intervals spanned sediments at all depths (0 - 19 ft); specifically, surface (0 - 0.05 ft), intermediate (0.05 - 10 ft), and deep (10 - 19 ft). Results were highly heterogeneous (Appendix F). For example, Cores VC3 and VC4 have maximum TOC concentrations at the surface. In Core VC3, TOC steadily decreases with depth while in Core VC4 it decreases then starts to increase at a depth of around 10 ft from the surface. In contrast, at Core VC6, the lowest TOC concentrations are observed at the surface. The results for these cores indicate no relationship between depth and TOC.

A fractionation analysis of OTB sediments was conducted in a separate study by The Dow Chemical Company. Results of the fractionation study, presented in Appendix D, show that a correlation exists between TOC and PCDD/F TEQ levels in the fine subfractions (silts and clays) of the samples that underwent the analysis. Without particle segregation, the heterogeneity of the sample likely confounded the correlation analysis between TOC and TEQ levels. Thus, relatively poor correlations were derived when comparing TOC and TEQ form bulk sediment samples. It should be noted that the fractionation study data were analyzed separately and are not discussed in detail herein. The results of the fractionation study are presented in a separate report provided in Appendix D.

4.3 Study #2 – Sixth Street Turning Basin Results

A primary objective of this study was to determine the potential effectiveness of the SSTB as a trap for sediments and sediment-associated contaminants. Related objectives were to develop and evaluate a range of tools available to measure trap efficiency by monitoring solids transport in the water column (suspended load) and near the sediment bed (bedload), and to collect data that will support modeling efforts to evaluate the long-term performance effective sediment trap. This section presents the study results and discusses them in the context of these primary objectives.

Determining the relative rates of transport of both solids and solids-associated dioxins and furans is a critical element of this work effort, with direct implications for sediment trap performance. Relative rates of suspended and bed-based transport relate to the amount of material that can be trapped, the overall rate of solids accumulation and corresponding sediment trap maintenance procedures, and the persistence of the trapped material.

The results of this evaluation demonstrate a relatively low efficiency for trapping suspended solids and a relatively high efficiency for trapping bedload solids. These results are unsurprising, as bedload solids tend to consist of heavier, larger-grained particles than suspended solids, which consist of finer-grained particles. The strong association between elevated dioxin and furan levels and the coarser materials measured in bedload and sediment trap sample units forms a preliminary rationale for focusing the sediment trap on the capture of bedload materials.

This section presents hydrodynamic, sediment transport, and mass balance results that focus on suspended solids transport and deposition in the SSTB. Bedload and sediment trap sample unit results that quantify sediment transport and characteristics of sediment deposits also are presented.

4.3.1 Background: Suspended Sediment and Bedload Sediment Transport

Sediment transport in a river system consists of suspended solids and bedload. The distribution is dynamic and based on particle size and buoyancy characteristics and the energy available to maintain particles in suspension, which is primarily a function of river velocity, water depth, and SSC in the water column.

Suspended solids typically consist of clay-to-silt particles transported in the water column. Bedload is characterized by particles that roll (saltate) along the river bottom without being brought into suspension. During transport, bedload remains in close proximity to the river bed, at the bottom of the water column, and therefore bedload concentration measurements (i.e., capture of bedload at the bottom of the water column) are distinct from SSC measurements.

The relative PSD of bedload and suspended load changes with velocity. At higher velocities, a greater proportion of the particle distribution is transported as suspended solids, resulting in a coarsening of the PSD in the water column, and also a coarsening of bedload solids as larger particles are suspended. Conversely, decreased velocities result in the settling of larger particles too heavy for either suspended sediment or bedload transport. Once settled from the water column, sediment bed particles tend to associate with the sediment bed via consolidation and cohesive forces, and consequently require greater energy (higher velocities) to resuspend.

The relative proportions of suspended and bedload sediment transport in the SSTB, coupled with their associated chemical concentrations, suggest that a sediment trap designed to capture bedload materials would be highly effective.

4.3.2 Hydrodynamic Conditions

Flow and water elevation were measured during three monitoring events (November 2006, March 2007, and July 2007) on the Saginaw River to capture a range of flow conditions. In the Saginaw River and its tributaries, discharge typically peaks in March and April and is lowest in August (Figure 4-9).

The Saginaw River discharge measured at the United States Geological Survey (USGS) gauge located at Rust Avenue (Figure 4-10) is shown on Figure 4-11 for each of the three events monitored for this study. The March 2007 High-Flow event was determined to have a 3-year recurrence interval, which satisfied the goal of monitoring a wet-weather event under high-flow conditions.

Saginaw River flow is greatly affected by Saginaw Bay water levels. Winds on Lake Huron contribute to seiche effects, and the large amount of storage capacity upstream of the City of Saginaw in the Shiawassee National Wildlife Refuge attenuates flood peaks in the Saginaw River. According to daily discharge records, seiche effects causing flow reversals during low-flow conditions have occurred at the Rust Avenue Bridge in Saginaw, approximately 2 miles downstream of the confluence of the Tittabawassee and Shiawassee rivers. Flow reversals are more common during summer months due to increased Saginaw Bay water levels in combination with reduced Saginaw River flows, as observed at the SSTB during the July 2007 event.

Seiche effects historically have made accurate Saginaw River mid- and low-flow measurements difficult. A statistical relationship between Saginaw River flow and its upstream tributary gauge data was developed by LimnoTech (LTI) in the late 1970s to determine Saginaw flows during periods when USGS data were not available. This statistical relationship was recently updated to accommodate improved, higher-frequency flow monitoring data. Figure 4-11 shows discharge rates reported from the USGS gauge station and compares those rates to LTI modeling results. The results show a strong correlation between the USGS and modeled discharge rates. During the July 2007 Low-Flow event, the model was used to extrapolate flow velocities for periods without USGS-reported flow rates.

A combination of hydrodynamic conditions (e.g., reduced scour potential and low stream velocities) makes the upper Saginaw River—including the SSTB—a highly depositional system. Saginaw River velocities are generally low due to its gradual slope, relatively large cross section, and seiche and Saginaw Bay backwater impacts. These lower velocities create a generally depositional environment, increasing the likelihood of settling of suspended and bedload solids entering the river. Furthermore, the storage provided by the confluence area just upstream of the river attenuates flood flows, and reduces peak flow velocities during wet weather as well as scour potential during high-flow events.

4.3.2.1 Range of Measured Flow Conditions and Velocities

An ADCP was used to generate discharge profiles at three transects in the study area during each of the three sampling events. The discharge transects coincided with the sampling transects that were located upstream, downstream, and in the center of the SSTB. A summary of the ADCP data generated during the three sampling events including transect location, transect width, total area, mean velocity, discharge, and results from moving bed tests during the March 2007 High-Flow event are presented in Tables 4-5a-d. The moving bed test was primarily conducted for quality assurance as part of the field procedures for conducting ADCP measurement of flow, and is included here primarily as a measurement of the error introduced by potential movement of the sediment bed during the ADCP surveys. Relatively small rates of bed movement were calculated relative to the measured stream velocities, as provided in Table 4-5d. These results indicate that error introduced by bed movement is small. In fact, bed movement may actually be too small to measure by this method – the reported numbers are on the order of 1-2 cm/sec, which could be attributable to boat movement even when anchored.

Figures 4-12a–c show velocity for cross sections of the river at the upstream and downstream transects, using ADCP data representative of conditions encountered during each of the three monitoring events. The cross sections reveal relatively homogenous flows across the river during the November 2006 and July 2007 Medium- and Low-Flow events, indicating a well mixed river with little apparent vertical or lateral velocity stratification. During the March 2007 High-Flow event, velocities were stratified laterally, especially in the SSTB, with higher velocities in the middle of the channel; vertically, velocities were more homogenously distributed.

In general, water velocities tended to be uniformly distributed vertically in the water column, though velocities tended to diminish near the channel bottom during the March 2007 High-Flow event when discharge ranged between approximately 13,000–24,000 cfs. The distribution of water velocity magnitudes varied laterally across the river by event.

Measured river discharge ranged from 4,094 cfs–7,564 cfs during the November 2006 Medium-Flow event, 12,946 cfs–23,915 cfs during the March 2007 High-Flow event, and -1,805 cfs (upstream flow) to 2,255 cfs during the July 2007 Low-Flow event.

River (transect) widths did not vary greatly (CV <0.05) with differing discharge levels over the sampling events. Transect widths averaged 516 ft across (CV=0.017) at the upstream location, 870 ft across (CV=0.006) at the SSTB, and 512 ft across (CV=0.031) at the downstream location. Water depths were shallowest along the west side of the study area. Water depths during the November 2006 Medium-Flow event ranged up to a maximum of approximately 17.5 ft (13.9 ft average) at the upstream transect and 22.5 ft (15.8 ft average) at the downstream transect (measurements were not conducted in the SSTB during this event). During the March 2007 High-Flow event, maximum water depths ranged up to approximately 30 ft at the west-central portion of the SSTB transect (21.5 ft average), up to 19.5 ft (14.5 ft average) upstream, and 26 ft (16.4 ft average) downstream. During the July 2007 Low-Flow event, maximum water depths ranged up to 17 ft (13.1 ft average) at the upstream transect, 29.5 ft (19.6 ft average) at the SSTB transect, and 23.5 ft (14.5 ft average) downstream.

4.3.3 Suspended Sediment Concentrations

SSC was measured to support the development of a mass balance of sediment entering and exiting the SSTB. This section discusses the measurements determined during the three flow events.

4.3.3.1 Short-Term Event-Based Suspended Solids Concentrations

OBS-TSS results for the each of the three events are shown in Figures 4-13a–c. The averages of OBS-TSS concentrations across each transect are summarized in Table 4-6 for the three sampling events.

For the November 2006 Medium-Flow and March 2007 High-Flow events, OBS-TSS concentrations were generally constant with depth through the water column, consistent with the velocity profiles that demonstrated a well mixed system, particularly during medium- to high - flow conditions. During the July 2007 Low-Flow event, when flows were very low, higher OBS-TSS concentrations were observed in the deepest portions of the water column. These data suggest some vertical stratification during extremely low-flow conditions. The TSS concentrations measured by the automatic samplers installed upstream and downstream of the SSTB are shown in Figure 4-14.

Average OBS-TSS transect concentrations were highest during the March 2007 High-Flow event. These concentrations measured 89 milligrams per liter (mg/l), and 85 mg/l in the upstream and downstream transects, respectively, on the first day of sampling (March 23, 2007) and decreased steadily throughout the event to 29 mg/l in both the upstream and downstream transects on the last day of sampling (March 28, 2007).

Average OBS-TSS transect concentrations were lowest during the July 2007 Low-Flow event, ranging from 15.5–45 mg/l in the upstream transect and from 15–41 mg/l in the downstream transect.

For the November 2006 Medium-Flow event, average OBS-TSS transect concentrations ranged from 11-23 mg/l in the upstream transect and from 11–20 mg/l in the downstream transect. In the center transect OBS-TSS concentrations increased from approximately 19 mg/l to 39 mg/l at a depth of approximately 21 ft (Figure 4-13a), which occurred as a ship was observed entering the turning basin.

In summary, SSC measured with the OBS showed:

1. A strong response to wet weather, increasing twofold during the March 2007 High-Flow event.

2. A high degree of vertical mixing, except during the lowest flow conditions.

3. Generally very similar concentrations at the upstream and downstream ends of the SSTB, suggesting relatively little suspended solids loss in the turning basin as currently configured.

These observations are further quantified in Section 7.4, which presents a mass-balance analysis of suspended sediment passing through the SSTB.

4.3.3.2 Long-Term Continuous Monitoring of Suspended Solids Concentrations

SSC for the Saginaw River were monitored continuously upstream of the SSTB from April–December 2007 with an OBS meter. The OBS meter was deployed in April 2007 to the middle of the water column. In August, the meter was moved to the bottom of the water column (near the sediment bed) to better capture bedload solids transport. The meter was retrieved in December 2007.

TSS concentrations calculated from the OBS data for the long-term-hydrodynamic monitoring study are shown in Figure 4-15. With the exception of late June 2007, the TSS concentrations were generally higher for the second half of the study when the instrument was moved to the bottom of the river from the original mid-channel depth. The spike in TSS at the end of June 2007 coincides with a rain event (0.55 inches) on June 27, 2007.

4.3.3.3 Suspended Particle Size Distributions

PSD profiles were measured throughout the water column at the three sampling stations (East, Center, and West) across the upstream and downstream transects and compared for the three sampling events. Example PSDs are shown in Figure 4-16 for each of the monitoring events. The cumulative PSDs are included in Appendix G. PSD data collected at the long-term hydrodynamic monitoring installation are summarized on Figure 4-17.

Over the course of the November 2006 Medium-Flow event, approximately 50% of the particles were within the clay and silt size range, and there was little PSD variation with depth. In general, PSD was similar from upstream to downstream on November 14 and 21, with the exception of the lower-velocity west channel on the 21st. At this location, the PSD was coarser upstream, indicating a deposition of coarser particles. On November 28, there was no difference in east channel PSD, but the center channel was slightly coarser downstream and the west channel was again slightly coarser upstream.

Samples from the March 2007 High-Flow event showed a much higher percentage of finer material (clay and silt) suspended in the water column. On the highest-flow days, 80% to 90% of the particles were within the clay and silt size range. As flow declined over the event, the percentage of finer particles was reduced to approximately 50%. These results suggest that high-flow events can have a significant impact on the suspended transport of clays and silts, but may not have a proportional impact on the suspension of coarse-grained sediment.

On the rising limb of the hydrograph (as peak flow approached), particles were slightly coarser downstream, particularly at the bottom of the channel. Close to peak flow, there was no PSD variation between upstream and downstream or with depth and the highest percentage of clay and silt particles was observed. On the falling limb of the hydrograph (after peak flow was reached), particles were generally coarser but there was little variation between upstream and downstream PSD.

Saginaw River flow during the July 2007 Low-Flow event was very low and flows moved in both the upstream and downstream directions during the three days of sampling. The November 2006 Medium-Flow and March 2007 High-Flow events did not show much PSD variation with depth. The July 2007 showed some variation with depth, with a higher median particle size near the surface. The coarsest particles appear to be in the lower-velocity west channel. The July 2007 event also shows a wider range in particle sizes than the November 2006 and March 2007 events.

The long-term hydrodynamic monitoring installation included a LISST-100 to measure PSD every 15 minutes. The instrument was installed from April to November 2007. In early August the instrument was moved from a position at mid-depth to near the river bottom. The results are summarized in Figure 4-17 to show PSD at the 10th, 50th (median), and 90th percentiles. The graphs show that the PSD was more variable over the earlier time period at the mid-depth installation. This variability (cyclical increasing trends) in particle size was caused by biogrowth accumulation on the instrument between cleaning and maintenance events, so much of the data from the mid-depth installation is not representative of actual water column solids PSD. The biogrowth buildup over time on the instrument explains why, in general, particle sizes measured at the mid-depth installation appear larger than those at the bottom installation. However, it can also be noted that Saginaw River flows were higher during the time period of the mid-depth installation compared to the bottom installation. A biogrowth inhibitor was added to the instrument in June 2007.

The major observations of the PSD analysis were as follows:

- Wet weather results in a greater proportion of fines in the transported suspended sediments, and greatest proportion is observed under peak flow conditions. This is likely due to resuspension and transport of fine materials throughout the watershed and tributaries that contribute to the lower Saginaw River.

- Under all conditions, relatively little difference was observable between PSD measurements from upstream and downstream of the SSTB. This suggests that, for the broad range of events monitored, deposition and retention of suspended solids from the SSTB is not great enough to significantly alter the PSD.

- The long-term installation shows lower SSC and highly variable particle size at the mid-depth installation, with slightly larger particle size overall. The near-bottom installation showed higher concentrations of suspended sediment, lower variability in particle size, and slightly finer particles overall. The observed higher variability in particle size in the mid-depth installation is likely related to a greater amount of suspended organic material.

Overall, the particle size data show results consistent with the SSC measurements: a significant response to wet weather, and relatively low efficiency in trapping suspended materials. These observations are quantified in the mass balance that follows.

4.3.4 Mass Balances, Comparing Upstream, and Downstream Solids Transport

The mass balance provides a way to examine the depositional behavior of sediment and allows for the quantification of sediment removal (erosion) or settling, providing a measure of the present-day effectiveness of the SSTB to capture suspended sediments and associated contaminants. The mass balance can be expressed as:

Mass into the system = Mass out of the system +/- Change in storage within the system.

The mass entering or leaving the system is equal to the volumetric flow rate of water multiplied by the concentration of sediment suspended in the water column. The TEQ mass entering or leaving the system is equal to the corresponding sediment mass multiplied by its corresponding TEQ concentration.

4.3.4.1 Mass Balance Approach

Figure 1-1 presents a simple conceptual model of sediment transport through the SSTB, in which upstream sediment mass is transported into the SSTB, a portion is captured due to particle settling and deposition, and the remaining sediment mass is transported downstream, out of the SSTB.

For this study, sediment mass entering the SSTB was measured at the upstream transect, sediment mass exiting the system was measured at the downstream transect, and the difference between the two transects indicated the net amount of sediment deposited (or removed). Field parameters measured at each transect included cross-sectional areas, flow velocity, SSC, and TEQ levels of suspended sediments. Measurements were taken during each flow event and at various event stages (e.g., during the rise, peak, and fall of the hydrograph).

TSS concentrations were determined from OBS measurements taken at three locations across each transect (upstream and downstream), dividing the river channel into three horizontal sections (East, Center, and West). OBS-TSS and velocity ADCP measurements were determined for five vertical bins covering the depth of the river in each of the three horizontal channels, for a total of 15 bins of data. To calculate the TSS mass load at each transect, average velocity and TSS concentrations were multiplied to determine the mass load for each bin; these were summed across the 15 bins. LISST-100 also was used to measure suspended solids, and provided information regarding the PSD of solids in the water column during sampling. However, OBS provided a more consistent and robust method for determining SSC.

4.3.4.2 Mass Balance Results

The mass of solids moving into (at the upstream transect) and out of (at the downstream transect) the SSTB during each of the three sampling events is summarized in Table 4-7a–c and shown in Figure 4-18. Negative values (upstream sediment mass greater than downstream sediment mass) indicate net deposition in the SSTB, and positive values (downstream sediment mass greater than upstream sediment mass) indicate net release of sediment from the SSTB.

In November 2006, deposition was observed across the SSTB from the upstream to downstream transect on November 21, with a solids loss of 8% in the morning. On November 28, resuspension occurred in the morning, with a 70% increase in solids, suggesting net solids export. Afternoon measurements showed a 7% reduction in solids load across the SSTB. The Saginaw River flow measured with the ADCP was lower on November 28 than on November 21, but a 1,700-cfs flow increase from upstream to downstream on the morning of November 28 may have increased the solids load exiting the SSTB.

Data from the July 2007 Low-Flow event shows deposition occurring in the SSTB similarly to the November 2006 Medium-Flow event, but on a smaller scale due to the lower July flows. In addition, some of the ADCP measurements showed flow reversals. The mass balance calculated for the morning of July 9 and the afternoon of July 10 showed 47% and 30% reductions in solids load, respectively. However, the upstream solids load in July 2007 was only approximately 20% of the load measured in November 2006.

The March 2007 event exhibited a much higher mass of deposition and suspension due to much higher flows. A large deposition of solids occurred at the beginning (the morning of March 23) of this high-flow event, resulting in a 5% loss. This deposition in the SSTB is an order of magnitude greater than the deposition observed during the November sampling event. As flow peaked—and during the initial decline—resuspension of particles occurred. As flow decreased on the fourth sampling day, deposition was again apparent with a 19% loss in the morning and a 6% loss in the afternoon.

4.3.5 Sediment Trap and Bedload Monitoring Results

The primary goal of the bedload and sediment trap monitoring was to capture sufficient deposited sediment and bedload material for the assessment of physical properties of the captured sediment and associated TEQ levels. Laboratory analytical reports are presented in Appendix C. Sediment trap and bedload sampling unit deployments were not designed to provide a measurement of the rate of transport of near-bed solids. Such measurements may be taken as a follow-up to this study to further quantify the observations of bedload deposition made on the basis of bathymetric surveys described in Section 4.3.

4.3.6 Sediment Trap and Bedload Particle Size Distributions

Sediment trap sampling units were deployed along transects upstream, downstream, and within the SSTB to determine gross sedimentation rates under varying flow conditions. Sediment trap samples were collected during the Medium- and Low-Flow events (November 2006 and July 2007), but not during the March 2007 High-Flow event because of the difficulties involved in deploying and retrieving sediment trap sampling units during severe weather. Bedload samples were collected during all three events;

however, PSD could not be determined for the Medium- and Low-Flow events due to insufficient sample volume.

The size distribution of sediment particles collected within the traps is presented in Tables 4-8 and 4-9 for the November 2006 and July 2007 events, respectively. Average PSD values were calculated for sediments collected in the traps along the upstream, downstream, and SSTB transects during the November 2006 Medium-Flow event. The collected sediments were dominated by silts, fine sands, and medium sands. In the upstream transect, silts comprised 54% of the trapped sediments, while in the SSTB and the downstream transects, the silt fraction decreased and was replaced by a higher fraction of medium sands (Figure 4-19).

Figure 4-20 shows the average PSD of sediments collected during the July 2007 Low-Flow event. During this event, silts comprised more than 67% of the sediments collected. As during the November Medium-Flow event, sediments trapped in the upstream transect contained a slightly higher silt fraction (79%) and smaller sand fraction than those trapped in the SSTB and downstream transects. Because of the very low flow velocities that characterized the July event, few larger and heavier sand particles were suspended in the water column and available for deposition in the sediment trap.

Figure 4-21 shows the average PSD of the bedload samples collected upstream, and downstream of the SSTB during the March 2007 High-Flow event. Detailed results are presented in Table 4-10. During this event, bedload was dominated by medium sand, followed by fine and coarse sand, silt, and gravel. The downstream transects had a substantially lower proportion of medium sand than the upstream transect.

In summary, samples from the upstream transect generally contained a higher fraction of medium and coarse sand as compared to the downstream transect, while the percentage of silt and fine sand was generally higher in the bedload at the downstream transect. These results suggest that medium and coarse sand bedload is preferentially removed in the SSTB. As noted above, bedload particle size was substantially coarser than sediment trap particle size.

The long (6–8-hour) bedload sampler deployments used in this study are not appropriate for making estimates of bedload flux. As the bedload samplers fill, the mesh that retains the sediment sample fills and clogs, reducing bedload trap efficiency with time. Bedload flux can be measured, but requires much shorter deployments. At this stage of this investigation, estimates of bedload flux and deposition are best determined by inference from the depositional patterns observable in the bathymetric data.

4.4 Suspended Sediment, Bedload, and Sediment Trap TEQ Levels

PCDD/F measurements were made for suspended solids, bedload, and sediment captured by sediment trap sampling units. PCDD/F results are reported as TEQs in this section to quantify their distribution and to assess the efficacy of the SSTB in capturing TEQs.

4.4.1 Suspended Sediment TEQ Levels

Suspended sediments collected during the three sampling events were analyzed for TEQ levels (Tables 4-11 to 4-13). During the November 2006 Medium-Flow event, suspended sediment TEQ levels were equal or less than 19.0 ppt in 14 samples collected upstream and downstream of the SSTB (Figure 4-

22). During the July 2007 Low-Flow event, suspended sediment continued to demonstrate low TEQ levels; upstream samples were below 29.8 ppt and downstream samples were below 48.7 ppt (Figure 4-23). During the March 2007 High-Flow event, TEQ levels of the suspended samples were generally low. All five downstream samples were below 60.0 ppt, and three of the four upstream samples were below 44.9 ppt (Figure 4-24). One upstream sample had a TEQ concentration of 3,895 ppt, almost two orders of magnitude higher than any other suspended sediment sample from the three sampling events. The 3,895 ppt result highlights the natural heterogeneity of the system: low TEQ levels (below 60 ppt) dominate the suspended load, but concentrations greater than 1000 ppt are possible, though infrequent.

A summary of suspended sediment TEQ levels across all three sampling events is provided in Figure 4-25. The median upstream TEQ is 10.6 ppt while the median downstream TEQ is 18.5 ppt; the median across both the upstream and downstream samples across all three sampling events is 12.5 ppt. Statistical analyses also were performed on the TEQ levels of suspended sediments by applying the two-sample t-test to natural-log-transformed data. No statistically significant differences were observed between the means of the upstream and downstream samples at the 95% level of confidence. The p values (statistical significance is represented by a p value <0.05) for the November 2006, March 2007, and July 2007 events were 0.21, 0.53, and 0.09, respectively (Table 4-14).

4.4.2 Sediment Trap TEQ levels

The sediments collected from the sediment trap sampling units were analyzed for TEQ levels. During the November 2006 Medium-Flow event, TEQ levels in sediments collected upstream of the SSTB (Samples SR-US-1, SR-US-2, and SR-US-3) were low and ranged from 40.7–102 ppt (Figure 4-26, Table 4-11). Six of the seven samples collected within the SSTB had TEQ levels below 1,768 ppt; however, sediment collected from the SR-TB-South-2 sampling unit location had a much higher TEQ level (18,189 ppt). A sample from one of the two downstream locations, SR-DS-3, also had relatively high TEQ (10,896 ppt), while the second downstream sample was low (53.0 ppt).

The TEQ levels of the sediment trap samples collected during the July 2007 Low-Flow event are provided on Figure 4-27 and Table 4-13. As during the November 2006 Medium-Flow event, samples collected from the upstream transect during the Low-Flow event were low and all three locations had TEQ levels below 110 ppt. All nine sediment samples collected within the SSTB also had low TEQ levels, ranging from 68.4–540 ppt. Downstream transect TEQ levels ranged from 213–4,206 ppt.

Statistical evaluation of the sediment trap samples showed no significant differences between the means of the upstream and downstream samples at the 95% level of confidence. The p values for the November 2006 and July 2007 events were 0.51 and 0.15, respectively. Relationships among samples within the SSTB were also calculated; no correlations were found (Table 4-14).

4.4.3 Bedload TEQ levels

Sediments collected in the bedload samplers during the three sampling events were analyzed for TEQ levels. Bedload samples collected upstream and downstream of the SSTB were variable. Upstream samples collected during the November 2006 Medium-Flow event contained TEQ levels below 770 ppt for all but one sample taken from SR-US-3, collected on November 21, which had a concentration of

26,543 ppt (Figure 4-28 and Table 4-11). The TEQ levels of bedload sediments collected from the downstream transect during this sampling event ranged from 145–32,593 ppt.

During the March 2007 High-Flow event, two samples from the upstream transect (from the SR-US-3 location had concentrations of 10,179 and 11,503 ppt; all remaining samples were equal to or less than 195 ppt (Figure 4-29 and Table 4-12). Downstream bedload concentrations varied between 7.18-4,465 ppt.

Due to the low velocity of flow during the July 2007 Low-Flow event, bedload transport rates were very low (Figure 4-30 and Table 4-13). To collect sufficient bedload volume for TEQ analysis, the samplers were installed each morning and removed at the end of each day for three consecutive days. Samples from each location were composited, resulting in a single cumulative sample for each location. Bedload TEQ levels at the upstream transect ranged from 17.1-21.3 ppt; TEQ levels at the downstream locations were 267 and 1,658 ppt.

For all three sampling events, the median TEQ of all upstream locations was 60.0 ppt; the median TEQ of all downstream locations was 495 ppt (Figure 4-31). The two-sample t-test was run for each of the sampling events. The results show no statistically significant differences between the means of the upstream and downstream samples at the 95% level of confidence; p values for bedload samples collected in November 2006, March 2007, and July 2007 events were 0.14, 0.22, and 0.16, respectively (Table 4-14).

4.4.4 Correlation of TEQ and TOC Levels

Bedload TOC levels were highly heterogeneous, ranging from ND–434,000 mg/kg (43.4%). Results also were highly variable at given bedload locations. For example, at the downstream-east bedload location, samples collected on three different days exhibited TOC concentrations of 434,000, ND, and 10,500 ng/kg (1.05%). These highly variable results, (Table 4-15) do not correlate with TEQ concentration.

5 Summary and Conclusions

A Technical Workgroup, convened as part of the ADR process, conducted field studies to evaluate the feasibility of a large-scale sediment trap to manage sediment transport and deposition in the Saginaw River. The work was completed over a 16-month period between September 2006 and December 2007. Study #1 included the coring and fractionation of sediments from the OTB and Study #2 evaluated the performance and feasibility the SSTB as a sediment trap.

A continuous supply of sediment from rainfall runoff, snowmelt, and river channel erosion points to the need for routine and long-term sediment management to facilitate vessel navigation on the Saginaw River and in Saginaw Bay. There is no indication of change in the scope of maintenance dredging work performed by USACE in long-range planning forecasts prepared periodically by the local district. Thus, the opportunity to merge navigation and environmental work appears to be viable for the foreseeable future.

5.1 Summary of Project Goals

A large-scale sediment trap can potentially reduce long-term maintenance requirements for the navigation channel by facilitating the deposition of solids in the trap and thus minimizing downstream sediment transport and deposition. The simple concept is to capture sediment in a relatively confined area, by accelerating deposition nearer its source (e.g., shortly after the confluence of the Shiawassee and Tittabawassee rivers), so that long-term maintenance dredging can be confined to a smaller area (i.e., in the large-scale sediment trap itself) and is required less frequently downstream of the sediment trap. In the Tittabawassee River/Saginaw River/Saginaw Bay system, the sediment trap also has the advantage of capturing furan and dioxin contaminants associated with sediment particles, enhancing source control by reducing downstream contaminant transport.

The primary goals of this investigation were to:

- Develop and evaluate a suite of state-of-the-art tools for characterization of the performance and efficacy of a sediment trap.
- Establish a suspended-sediment mass balance across the sediment trap to estimate baseline (current conditions) sediment and contaminant mass deposition in the traps over time and under varying flow regimes.
- Assess the (current and potential) efficacy of a field-scale sediment trap to capture and remove sediment and reduce USACE maintenance dredging requirements.
- Evaluate the (current and potential) efficacy of a field-scale sediment trap to capture and remove contaminated suspended sediments from the Saginaw River.
- Gain information needed to model the long-term performance of a sediment trap in the upper Saginaw River.

Together, the results of our investigations highlight the advantages of merging USACE navigation channel maintenance activities conducted at the turning basins with environmental restoration goals to address Upper Saginaw River sediments containing PCDD/F.

5.2 Summary of Study Results

5.2.1 Study #1 – Ojibway Turning Basin Results

- Four distinct layers of sediment deposits, or strata, are evident within the sediment cores collected within the OTB: OS I, OS II, G, and B.
- The moisture content of the samples was reported between 15– 132% (by mass), with an average moisture content of 52%. Stratum OS I typically had higher moisture content (average 85%) than other strata. Averages for strata OS II, G, and B were 32%, 52%, and 15%, respectively.
- The average bulk density for stratum OS I was 603 kilograms per cubic meter (kg/m3). Average bulk density values for strata OS II, G, and B were 1135 kg/m3, 910 kg/m3, and 1,484 kg/m3, respectively.
- BC concentrations ranged from 0.05%–1.41%, and averaged 0.37%. The highest levels occurred in stratum OS I, which averaged approximately 0.52%. Averages for strata OS II, G, and B were 0.18%, 0.38%, and 0.05%.
- TOC concentrations in OTB sediment ranged from 0.05–3.49%, averaging 1.49%. The highest levels of TOC occurred in stratum OS I, where average TOC was approximately 2.47%. Average TOC concentrations in strata S, gray silt/clay (GSC), and RC were 0.45%, 1.13%, and 0.22%, respectively.
- No statistically significant correlations were observed between TEQ concentrations and TOC or BC concentrations.
- Natural deposition of increasingly clean sediment with time has led to decreasing surface sediment TEQ levels; vertical TEQ profiles in the OTB sediment cores reveal a depositional profile with higher TEQ levels in buried sediments and lower concentrations at the sediment surface.
- TEQ concentrations in the OTB sediment cores ranged from 0.723–10,748 ppt with a median of 182 ppt.
- TEQ levels increase with sediment depth, reaching the highest concentrations 4–10 ft below the sediment-water interface; in much deeper sediments, TEQ levels progressively decrease to below 10 ppt.

5.2.2 Study #2 – Sixth Street Turning Basin Results

- Suspended sediment transport was dominated by silt particles and some clay particles; bedload transport was dominated by medium-to-fine sands and silt-size particles.

- In general, low TEQ concentrations were associated with suspended solids (generally less than 60 ppt). The concentrations were much lower than those measured in bedload and sediment trap samples.

- SSC measured with the OBS showed: 1) a strong response to wet weather, with a twofold increase in concentration during the March 2007 event; 2) a high degree of vertical mixing, except during the lowest flow conditions; and 3) generally very similar concentrations at the upstream and downstream ends of the SSTB, suggesting relatively low suspended solids loss in the SSTB (as currently configured).

- Wet weather results in a greater proportion of fines in the transported suspended sediments, and the greatest proportion is observed under peak flow conditions. This is likely due to resuspension and transport of fine materials throughout the watershed and tributaries that contribute to the lower Saginaw River.

- Under all conditions, relatively little difference was observable between suspended sediment PSD measurements from upstream and downstream of the SSTB. Thus—for the broad range of events monitored—deposition and retention of suspended solids from the SSTB was not great enough to significantly alter the PSD.

- The maximum trapping efficiency for suspended sediments was 16%.

- The long-term installation shows lower SSC and highly variable particle size at the mid-depth installation, with slightly larger particle size overall. The near-bottom installation showed higher concentrations of suspended sediment, lower variability in particle size, and slightly finer particles overall. The observed higher variability in particle size in the mid-depth installation is likely related to a greater amount of suspended organic material.

- The bedload and sediment trap samples showed a much wider range of TEQ concentrations than the suspended solids with concentrations, ranging from less than 10 ppt to greater than 30,000 ppt.

- The highest and most heterogeneous TEQ levels were associated with bedload.

5.2.3 Geophysical Surveys

- Comparison of bathymetric surveys conducted in November 2006 and September 2007 revealed a depositional area at the upstream end of the SSTB. More than 10,000 CY of sediment was deposited over a 2-acre area.

- Bathymetric surveys revealed a deepening and broadening of the western side of the SSTB, forming a crescent of relatively uniform elevation along its length. This apparent erosion area is likely due to ship propeller wash from turning maneuvers. The bathymetric comparison suggests that deep scouring is relatively confined to the west side and is largely independent of the 2-acre depositional area at the upstream end of the SSTB.

5.3 Model Development

This report is primarily intended as a summary of the data gathered to support an evaluation of the feasibility analysis of a sediment trap. The mass balances and preliminary data evaluations presented here are a first step toward a more comprehensive understanding of solids and contaminant transport through and retention within the sediment trap. In parallel with the data gathering effort described here, an effort is underway to develop a model that represents the hydrodynamics and sediment transport behavior of the SSTB. This model will be used to synthesize all the data across all media and event conditions, to support the evaluation of long-term trap performance, and to develop trap operation and maintenance procedures.

5.4 Conclusions

The Saginaw River and its watershed is "event-driven," meaning flows in the river are highly responsive to rain or snow-melt events. For this reason, hydrodynamic and sediment transport processes were measured over three "events" that captured one very low-flow period (July 2007), one moderately low-flow period (November 2006), and one very high-flow (3-year-recurrence) period (March 2007). For each event, the goal was to monitor water velocities and sediment transport over multiple days; for the high-flow event, this meant capturing the rise, the peak, and the fall of the river hydrograph during the rainfall event.

During each event, sediment transport was monitored as both suspended sediment transport and bedload transport. Suspended sediment transport was dominated by the transport of silt particles and some clay particles; bedload transport was dominated by medium-to-fine sands and silt-size particles.

In general, low TEQ levels were associated with suspended solids (<60 ppt was typical). Although slightly higher TEQ levels were observed with increased flow rates, the SSC range was still much lower than the maximum concentrations measured in the bedload and sediment trap samples. Thirty-seven suspended sediment composite samples were collected and analyzed for furan and dioxin TEQ levels. Except for one sample whose concentration was 3,895 ppt, all samples had concentrations less than 60 ppt. In contrast to the SSC, bedload and sediment trap samples revealed a much wider range of concentrations, ranging from less than 10 ppt to greater than 30,000 ppt. The highest and most heterogeneous TEQ levels were associated with bedload.

These results have important implications for managing suspended and bedload sediments. Of the two particle-size fractions, bedload is easier to trap because, as a coarser-size fraction traveling close to the bed, it requires a smaller reduction in velocity to influence and accelerate settling and deposition. The observation that the highest TEQ levels are associated with bedload means that trapping bedload will result in the capture of some of the highest TEQ levels in the river, limiting their downstream transport. The parameters that influence bedload transport include shear stress, velocity, friction, and sediment cohesiveness. An effective sediment trap must allow for capture of solids during a full range of flow conditions.

The suspended solids mass balance results presented here demonstrate some potential to trap suspended sediments, but a much lower capture efficiency (as compared to bedload) across the range of flow conditions is expected. Although suspended sediment removal efficiencies may be improved, the relatively low TEQ levels associated with suspended sediments suggests that a large investment in trapping the suspended load may not be cost effective. The low (generally <60 ppt) TEQ levels in suspended sediments limits the potential downstream accumulation of elevated TEQ levels via suspended load transport and deposition.

5.5 Next Steps

Results of this study lead to the following recommendations for efficient operation of the SSTB as a sediment trap:

- The sediment trap should be operated and maintained to capture and retain bedload solids consisting of relatively fine to coarse-grained sand particles, and should not target silts and clays typical of suspended solids in the water column.

- The sediment trap should be operated and maintained to capture and retain bedload solids during relatively high flow conditions when solids transport is highest and when there is the greatest potential for capture of solids and corresponding TEQs.

- Sediment trap operation and maintenance should consider storage capacity and sediment mass/volume accumulation rates under a full range of flow conditions anticipated in the Saginaw River.

Future activities and project planning will include 1) additional field studies, 2) modeling, and 3) communication with regulatory agencies and the public. Sediment transport modeling requires construction of a three-dimensional hydrodynamic model of the SSTB area. Hydrodynamic modeling will be used to examine the full range of flow conditions, sediment transport rates, and system stresses (e.g., ship traffic and propeller wash) expected in the sediment trap, and to evaluate the long-term performance of the sediment trap under these conditions.

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Tables

Table 3-1
Summary of Sediment Core Collection: Ojibway Turning Basin

Coring Location	Core Location, NAD83 MI South		Core Number	Penetration Depth (feet)	Recovery (feet)	Notes
	Easting	Northing				
VC-1	13,234,666	701,834	1	20.0	18.1	
VC-1	13,234,664	701,834	2	20.0	18.2	
VC-1	13,234,662	701,834	3	20.0	18.6	
VC-2	13,234,731	701,902	1	20.0	19.0	
VC-2	13,234,735	701,903	2	20.0	18.5	
VC-2	13,234,733	701,905	3	20.0	17.4	
VC-3	13,234,798	701,975	1	20.0	19.8	
VC-3	13,234,798	701,979	2	20.0	18.9	
VC-3	13,234,800	701,978	3	20.0	18.4	
VC-4	13,234,802	701,761	1	20.0	18.7	
VC-4	13,234,802	701,766	2	20.0	18.2	
VC-4	13,234,802	701,762	3	20.0	18.1	
VC-5	13,234,874	701,838	1	20.0	19.9	
VC-5	13,234,868	701,838	2	20.0	19.2	
VC-5	13,234,877	701,841	3	20.0	17.6	
VC-6	13,234,918	701,669	1	20.0	18.1	
VC-6	13,234,913	701,671	2	20.0	16.0	
VC-6	13,234,913	701,666	3	20.0	18.4	
VC-7	13,234,990	701,748	1	20.0	18.9	
VC-7	13,234,989	701,746	2	20.0	18.5	
VC-7	13,234,983	701,747	3	20.0	18.3	
VC-8	13,235,075	701,613	1	16.1	13.2	Refusal, pen rate 13 min/0.5 ft
VC-8	13,235,077	701,611	2	16.3	15.4	Refusal, pen rate 8 min/0.5 ft
VC-8	13,235,080	701,615	3	16.1	15.5	Refusal, pen rate 8 min/0.5 ft

Table 4-1
Dioxin/Furan Total TEQ Results: Ojibway Turning Basin Sediment Cores - November 2006

Sample ID	Location ID	Date Sampled	Total TEQ (pg/g)
VC1-00.0-00.5	VC1	30-Nov-06	182
VC1-04.0-04.5	VC1	30-Nov-06	249
VC1-08.5-09.0	VC1	30-Nov-06	962
VC1-11.9-12.4	VC1	30-Nov-06	1.27
VC1-18.0-18.4	VC1	30-Nov-06	1.29
VC2-00.0-00.5	VC2	30-Nov-06	318
VC2-04.0-04.5	VC2	30-Nov-06	359
VC2-08.5-09.0	VC2	30-Nov-06	814
VC2-13.0-13.5	VC2	01-Dec-06	5.36
VC2-13.0-13.5D	VC2	01-Dec-06	91.9
VC2-18.5-19.0	VC2	01-Dec-06	1.48
VC3-00.0-00.5	VC3	01-Dec-06	287
VC3-04.5-05.0	VC3	01-Dec-06	726
VC3-09.0-09.5	VC3	01-Dec-06	1105
VC3-13.8-14.3	VC3	01-Dec-06	32.0
VC3-18.5-18.8	VC3	01-Dec-06	0.826
VC4-00.0-00.5	VC4	01-Dec-06	89.0
VC4-00.0-00.5D	VC4	01-Dec-06	147
VC4-04.2-04.6	VC4	01-Dec-06	26.9
VC4-09.8-10.3	VC4	02-Dec-06	205
VC4-13.5-14.0	VC4	02-Dec-06	0.800
VC4-17.5-18.0	VC4	02-Dec-06	1.19
VC5-00.0-00.5	VC5	02-Dec-06	630
VC5-00.0-00.5D	VC5	02-Dec-06	377
VC5-02.5-02.7	VC5	02-Dec-06	1019
VC5-08.0-08.5	VC5	02-Dec-06	4904
VC5-11.0-11.4	VC5	02-Dec-06	480
VC5-18.5-19.0	VC5	02-Dec-06	1.74
VC6-00.0-00.5	VC6	02-Dec-06	339
VC6-03.2-03.7	VC6	02-Dec-06	649
VC6-05.9-06.3	VC6	02-Dec-06	2187
VC6-12.0-12.5	VC6	02-Dec-06	0.845
VC6-17.5-18.0	VC6	02-Dec-06	0.817
VC7-00.0-00.5	VC7	03-Dec-06	55.5
VC7-03.1-03.6	VC7	03-Dec-06	865
VC7-06.0-06.5	VC7	03-Dec-06	10748
VC7-12.0-12.5	VC7	03-Dec-06	1.32
VC7-18.0-18.5	VC7	03-Dec-06	0.723
VC8-00.0-00.5	VC8	03-Dec-06	10334
VC8-00.0-00.5D	VC8	03-Dec-06	16.9
VC8-00.5-01.0	VC8	03-Dec-06	103
VC8-02.5-03.0	VC8	03-Dec-06	56.3
VC8-03.0-03.4	VC8	03-Dec-06	490
VC8-08.0-08.5	VC8	03-Dec-06	1.18
VC8-15.0-15.4	VC8	03-Dec-06	0.764

Table 4-2
Sediment Physical Characteristics by Strata: Ojibway Turning Basin

Physical Characteristic		Ojibway Turning Basin Sediment Strata			
		Stratum (OS I)	Stratum (OS II)	Stratum (G)	Stratum (BC)
Particle Size Distribution	% Medium and Coarse Sand	6	60	6	14
	% Fine Sand	40	29	37	32
	% Silt	39	8	44	24
	% Clay	15	4	19	30
Average Moisture Content (%)		85	32	52	15
Average Bulk Density (kg/m^3)		603	1135	910	1484
Average Total Organic Carbon (%C)		2.47	0.45	1.13	0.22
Average Black Carbon (%C)		0.52	0.18	0.38	0.05

Table 4-3
TOC, BC, TM17, and TEQ Results: Ojibway Turning Basin

Field Sample ID	Depth (ft)	TOC %C	BC %C	TM17 (pg/g)	TEQ (pg/g)	log TCCD/Fs	log TEQ
VC1-00.0-00.5	0.5	3.06	0.61	5273	182	3.722	2.259
VC1-04.0-04.5	4.5	2.79	0.77	22830	249	4.359	2.395
VC1-08.5-09.0	9	2.79	0.92	68159	962	4.834	2.983
VC1-11.9-12.4	12.4	0.46	0.10	99	1.3	1.996	0.105
VC1-18.0-18.4	18.4	0.94	0.24	106	1.3	2.024	0.109
VC2-00.0-00.5	0.5	3.03	0.63	7747	318	3.889	2.502
VC2-04.0-04.5	4.5	2.67	0.33	22815	359	4.358	2.555
VC2-08.5-09.0	9	3.49	0.56	64449	814	4.809	2.910
VC2-13.0-13.5	13.5	0.10	0.10	437	5.4	2.641	0.729
VC2-13.0-13.5D	13.5			1260	92	3.100	1.963
VC2-18.5-19.0	19	1.20	0.26	162	1.5	2.210	0.172
VC3-00.0-00.5	0.5	2.86	0.75	9414	287	3.974	2.458
VC3-04.5-05.0	5	2.91	1.30	42533	726	4.629	2.861
VC3-09.0-09.5	9.5	2.66	0.64	168014	1105	5.225	3.043
VC3-13.8-14.3	14.3	0.55	0.10	2142	32	3.331	1.504
VC3-18.5-18.8	18.8	1.12	1.41	18	0.8	1.249	-0.083
VC4-00.0-00.5	0.5	2.20	0.26	3706	89	3.569	1.949
VC4-00.0-00.5D	0.5			3559	147	3.551	2.167
VC4-04.2-04.6	4.6	0.10	0.10	1702	27	3.231	1.430
VC4-09.8-10.3	10.3	0.17	0.10	11190	205	4.049	2.311
VC4-13.5-14.0	14	1.03	0.42	9.3	0.8	0.968	-0.097
VC4-17.5-18.0	18	1.21	0.37	27	1.2	1.438	0.077
VC5-00.0-00.5	0.5	1.83	0.29	10681	630	4.029	2.800
VC5-00.0-00.5D	0.5	2.29	0.47	20804	377	4.318	2.576
VC5-02.5-02.7	2.7	0.64	0.10	60062	1019	4.779	3.008
VC5-08.0-08.5	8.5	1.39	0.28	143875	4904	5.158	3.691
VC5-11.0-11.4	11.4	2.39	0.39	18712	480	4.272	2.681
VC5-18.5-19.0	19	1.07	0.14	48	1.7	1.684	0.242
VC6-00.0-00.5	0.5	0.18	0.10	2948	339	3.470	2.530
VC6-03.2-03.7	3.7	2.27	0.51	50615	649	4.704	2.812
VC6-05.9-06.3	6.3	0.44	0.18	21182	2187	4.326	3.340
VC6-12.0-12.5	12.5	1.12	0.25	8.6	0.8	0.935	-0.073
VC6-17.5-18.0	18	1.32	0.28	6.5	0.8	0.810	-0.088
VC7-00.0-00.5	0.5	0.19	0.10	641	55	2.807	1.744
VC7-03.1-03.6	3.6	2.19	0.31	63476	865	4.803	2.937
VC7-06.0-06.5	6.5	0.10	0.10	95087	10748	4.978	4.031
VC7-12.0-12.5	12.5	1.09	0.52	12	1.3	1.093	0.121
VC7-18.0-18.5	18.5	1.11	0.18	5.7	0.7	0.759	-0.141
VC8-00.0-00.5	0.5	0.10	0.10	90287	10334	4.956	4.014
VC8-00.0-00.5D	0.5			193	17	2.285	1.229
VC8-00.5-01.0	1			1063	103	3.027	2.014
VC8-02.5-03.0	3	0.11	0.10	2544	56	3.405	1.751
VC8-03.0-03.4	3.4	2.32	0.56	49087	490	4.691	2.690
VC8-08.0-08.5	8.5	1.34	0.21	17	1.2	1.232	0.073
VC8-15.0-15.4	15.4	0.22	0.10	7.9	0.8	0.899	-0.117

Table 4-4
Statistical Analysis: Obijway Turning Basin Sediment Cores

TOC and BC (%) versus TM17 and TEQ (pg/g) Concentrations		
Parameters	**Linear Fit, R^2**	**Spearman Coefficient**
Log(TM17) vs TOC	0.51	0.49
Log(TM17) vs BC	0.29	0.47
Log(TEQ) vs TOC	0.47	0.41
Log(TEQ) vs BC	0.26	0.29

TOC, BC (%), TCCD/Fs and TEQ (pg/g) versus Grain Size (%)	
Parameters	**Spearman Coefficient**
TOC vs Clay	0.33
TOC vs Sand	-0.49
TOC vs Silt	0.6
BC vs Clay	-0.07
BC vs Sand	-0.14
BC vs Silt	0.3
TCCD/Fs vs Clay	-0.34
TCCD/Fs vs Sand	0.27
TCCD/Fs vs Silt	-0.21
TEQ vs Clay	-0.39
TEQ vs Sand	0.35
TEQ vs Silt	-0.3

Table 4-5a
Sixth Street Turning Basin Discharge Summary
November 2006 - Medium Flow Event

Date	Time	Transect	Transect Width (ft)	Total Area (ft^2)	Mean Velocity (fps)	Discharge (cfs)
11/13/2006	13:10	U	506	6604	1.060	6995
11/14/2006	16:10	U	526	8322	0.849	7069
11/15/2006	10:25	D	519	8020	0.752	6018
11/15/2006	15:45	U	524	6894	0.834	5751
11/21/2006	11:00	U	521	6641	1.135	7539
11/21/2006	12:20	D	513	7837	0.966	7564
11/21/2006	14:40	U	491	7230	1.044	7533
11/21/2006	15:45	D	536	8261	0.845	6959
11/28/2006	9:00	U	497	6858	0.597	4094
11/28/2006	10:40	D	454	7574	0.760	5753
11/28/2006	13:40	U	497	6840	0.720	4921
11/28/2006	15:25	D	447	7263	0.649	4712

Each row represents the average values from 4 "runs" across each transect
U: upstream
D: downstream

Table 4-5b
Sixth Street Turning Basin Discharge Summary
March 2007 - High Flow Event

Date	Time	Transect	Transect Width (ft)	Total Area (ft^2)	Mean Velocity (fps)	Discharge (cfs)
3/23/2007	12:15	U	523	7544	2.39	18028
3/23/2007	12:35	C	887	19016	0.935	17782
3/23/2007	13:45	D	489	8417	2.233	18797
3/23/2007	14:25	U	527	7564	2.502	18927
3/23/2007	14:50	C	874	18716	1.103	20636
3/23/2007	15:35	D	493	8441	2.256	19038
3/23/2007	16:50	U	536	7855	2.61	20500
3/23/2007	17:45	D	541	8688	2.319	20150
3/24/2007	9:30	U	523	7902	2.822	22298
3/24/2007	10:45	C	883	19179	1.173	22496
3/24/2007	12:05	D	528	8820	2.595	22884
3/24/2007	14:40	U	535	8081	2.897	23405
3/24/2007	15:10	C	875	19459	1.229	23915
3/24/2007	16:00	D	523	8773	2.582	22653
3/26/2007	9:55	U	526	7516	2.751	20675
3/26/2007	10:35	C	848	18227	1.124	20472
3/26/2007	11:25	D	516	8402	2.438	20477
3/26/2007	12:00	U	527	7524	2.758	20754
3/26/2007	12:45	C	877	18501	1.103	20416
3/26/2007	14:30	C	886	19322	1.041	20118
3/26/2007	15:15	D	530	8680	2.341	20326
3/26/2007	16:00	U	526	7647	2.659	20331
3/26/2007	16:20	D	537	8740	2.335	20403
3/28/2007	9:00	U	509	7201	1.903	13697
3/28/2007	10:10	C	865	18487	0.749	13810
3/28/2007	11:10	D	537	8406	1.604	13453
3/28/2007	12:00	U	522	7352	1.855	13635
3/28/2007	12:15	C	868	17379	0.709	13035
3/28/2007	12:35	D	536	8346	1.555	12946

Each row represents the average values from 2 to 4 "runs" across each transect

U: upstream

C: center

D: downstream

Table 4-5c
Sixth Street Turing Basin Discharge Summary
July 2007 - Low Flow Event

Date	Time	Transect	Transect Width (ft)	Total Area (ft^2)	Mean Velocity (fps)	Discharge (cfs)
7/9/2007	11:30	U	521	6784	0.229	1551
7/9/2007	12:30	C	861	17302	-0.104	-1805
7/9/2007	13:00	D	530	7760	0.105	811
7/9/2007	13:40	U	507	6573	0.228	1500
7/9/2007	14:00	C	876	17352	0.044	768
7/9/2007	14:20	D	512	7648	-0.085	-653
7/10/2007	8:15	U	512	6712	0.054	361
7/10/2007	9:00	U	510	6678	-0.036	-239
7/10/2007	8:45	C	870	16897	0.098	1661
7/10/2007	9:40	D	505	7378	0.306	2255
7/10/2007	10:10	C	859	16926	0.056	940
7/10/2007	11:10	D	499	7010	0.112	787
7/10/2007	12:55	U	513	6795	0.083	561
7/10/2007	14:15	D	515	7606	0.268	2037
7/10/2007	14:35	U	511	6547	0.340	2225
7/10/2007	15:00	C	863	16388	0.088	1434
7/10/2007	15:30	D	519	7497	0.261	1953
7/11/2007	12:55	U	515	6787	0.257	1741
7/11/2007	13:45	C	868	17201	0.069	1190
7/11/2007	14:40	D	557	7871	0.019	149

Each row represents the average values from 2 to 4 "runs" across each transect

U: upstream

C: center

D: downstream

Table 4-5d
Sixth Street Turning Basin Moving Bed Test Summary
March 2007 - High Flow Event

Date	Time	Transect	Location	DMG (ft)	Time (sec)	Net Bed Movement Rate (ft/sec)	Net Bed Movement Direction	Wind Direction	Wind Speed (mph)	Wind Gusts (mph)
3/23/2007	17:10	U	C	15.66	234.42	0.067	Downstream	NNE	6.9	
3/23/2007	17:20	C	C	26.78	304.46	0.088	Upstream	NNE	6.9	
3/23/2007	17:55	D	C	13.90	298.78	0.047	Downstream	NNE	4.6	
3/24/2007	10:25	U	C	85.14	300.89	0.283	Downstream	SW	0 to 3.5	
3/24/2007	11:55	C	C	24.09	301.10	0.080	Downstream	W	6.9	
3/24/2007	12:30	D	C	28.85	318.50	0.091	Downstream	Wto WNW	9.2	
3/26/2007	12:30	U	C	24.06	300.76	0.080	Downstream	SW	20.7	27.6
3/26/2007	15:00	C	C	17.83	302.10	0.059	Upstream	WSW	20.7	32.2
3/26/2007	15:35	D	C	8.73	304.60	0.029	Downstream	WSW	23	35.7
3/28/2007	9:37	U	C	7.56	302.43	0.025	Upstream	NE	18.4	
3/28/2007	9:47	U	E	2.57	314.51	0.008	Upstream	NE	20.7	25.3
3/28/2007	10:00	U	W	6.05	303.52	0.020	Upstream	NE	20.7	25.3
3/28/2007	11:00	C	C	6.50	309.06	0.021	Upstream	ENE	25.3	28.8
3/28/2007	12:52	D	C	6.59	309.52	0.021	Upstream	NE	20.7	26.5

Moving bed test - boat is anchored in one location while deploying ADCP using bottom tracking feature
DMG: distance made good (start point to end point)
U: upstream
C: center
D: downstream
E: east
W: west
Wind source: www.weatherunderground (NWS-KMBS)

Table 4-6
Average of OBS-TSS Results by Transect for SSTB

Event	Day	UPSTREAM		DOWNSTREAM	
		Time	Average OBS-TSS (mg/l)	Time	Average OBS-TSS (mg/l)
Nov-06 Medium Flow Event	11/15/2006	PM	11	PM	11
	11/21/2006	AM	19	AM	18
	11/21/2006	PM	21	PM	20
	11/28/2006	AM	14	AM	19
	11/28/2006	PM	23	PM	14
Mar-07 High Flow Event	3/23/2007	AM	7	AM	87
	3/23/2007	PM	89	PM	85
	3/24/2007	AM	83	AM	80
	3/24/2007	PM	78	PM	78
	3/26/2007	AM	42	AM	41
	3/26/2007	PM	40	PM	39
	3/28/2007	AM	30	AM	29
	3/28/2007	AM	29	AM	29
Jul-07 Low Flow Event	7/9/2007	AM	24	AM	41
	7/9/2007	PM	35	PM	29
	7/10/2007	AM	20	AM	22
	7/10/2007	PM	20	PM	15
	7/11/2007	AM	16	AM	15
	7/11/2007	PM	45	PM	21

Table 4-7a
Mass Balance Summary for Suspended Solids using OBS: Sixth Street Turning Basin
November 2006 - Medium Flow Event

Date	Location	Total (kg/day)	Total (mt/day)	Total (mt/year)
11/21/06	US-E (12:26)	132,931		
	US-C (12:11)	128,493		
	US-W (11:45)	85,322		
	TOTAL	**346,746**	**347**	**126,562**
11/21/06	DS-E (13:19)	119,313		
	DS-C (13:00)	131,318		
	DS-W (12:44)	69,933		
	TOTAL	**320,564**	**321**	**117,006**
	East	-13,618		
	Center	2,824		
	West	-15,389		
DIFFERENCE	***TOTAL***	**-26,182**	**-26**	**-9,557**
			% Loss	**7.55%**

Date	Location	Total (kg/day)	Total (mt/day)	Total (mt/year)
11/28/06	US-E (13:36)	56,955		
	US-C (13:58)	56,935		
	US-W (14:19)	41,659		
	TOTAL	**155,548**	**156**	**56,775**
11/28/06	DS-E (14:44)	41,436		
	DS-C (15:10)	70,345		
	DS-W (15:34)	32,922		
	TOTAL	**144,703**	**145**	**52,817**
	East	-15,519		
	Center	13,411		
	West	-8,737		
DIFFERENCE	***TOTAL***	**-10,845**	**-11**	**-3,958**
			% Loss	**6.97%**

Date	Location	Total (kg/day)	Total (mt/day)	Total (mt/year)
11/28/06	US-E (9:59)	50,063		
	US-C (10:36)	49,842		
	US-W (11:06)	30,809		
	TOTAL	**130,714**	**131**	**47,711**
11/28/06	DS-E (11:48)	48,240		
	DS-C (12:16)	93,563		
	DS-W (13:08)	79,280		
	TOTAL	**221,083**	**221**	**80,695**
	East	-1,823		
	Center	43,720		
	West	48,471		
DIFFERENCE	***TOTAL***	**90,368**	**90**	**32,984**
			% Loss	**-69.13%**

Table 4-7b
Mass Balance Summary for Suspended Solids using OBS: Sixth Street Turning Basin
March 2007 - High Flow Event

Date	Location	Total (kg/day)	Total (mt/day)	Total (mt/year)
3/23/07	US-E (14:00)	1,913,588.44		
	US-C (12:31)	1,390,974.97		
	US-W (11:04)	944,264		
	TOTAL	**4,248,827**	**4,249**	**1,550,822**
3/23/07	DS-E (14:47)	1,656,797		
	DS-C (13:20)	1,539,352		
	DS-W (11:46)	814,309		
	TOTAL	**4,010,458**	**4,010**	**1,463,817**
	East			
	Center			
	West			
DIFFERENCE	***TOTAL***	**-238,369**	**-238**	**-87,005**
			% Loss	**5.61%**

Date	Location	Total (kg/day)	Total (mt/day)	Total (mt/year)
3/24/07	US-E (13:25)	1,368,775		
	US-C (12:05)	1,553,917		
	US-W (11:18)	1,411,212		
	TOTAL	**4,333,904**	**4,334**	**1,581,875**
3/24/07	DS-E (13:43)	1,659,075		
	DS-C (12:19)	1,664,749		
	DS-W (11:27)	1,111,785		
	TOTAL	**4,435,609**	**4,436**	**1,618,997**
	East			
	Center			
	West			
DIFFERENCE	***TOTAL***	**101,704**	**102**	**37,122**
			% Loss	**-2.35%**

Date	Location	Total (kg/day)	Total (mt/day)	Total (mt/year)
3/26/07	US-E (10:06)	694,297		
	US-C (11:11)	764,978		
	US-W (12:18)	552,987		
	TOTAL	**2,012,261**	**2,012**	**734,475**
3/26/07	DS-E (10:17)	777,222		
	DS-C (11:29)	797,093		
	DS-W (12:28)	453,703		
	TOTAL	**2,028,018**	**2,028**	**740,227**
	East			
	Center			
	West			
DIFFERENCE	***TOTAL***	**15,757**	**16**	**5,751**
			% Loss	**-0.78%**

Date	Location	Total (kg/day)	Total (mt/day)	Total (mt/year)
3/28/07	US-E (10:32)	241,940		
	US-C (9:57)	347,906		
	US-W (9:10)	280,228		
	TOTAL	**870,074**	**870**	**317,577**
3/28/07	DS-E (10:53)	221,118		
	DS-C (10:14)	272,298		
	DS-W (9:39)	211,689		
	TOTAL	**705,105**	**705**	**257,363**
	East			
	Center			
	West			
DIFFERENCE	***TOTAL***	**-164,969**	**-165**	**-60,214**
			% Loss	**18.96%**

Date	Location	Total (kg/day)	Total (mt/day)	Total (mt/year)
3/23/07	US-E (17:20)	1,545,909		
	US-C (16:36)	1,615,372		
	US-W (15:48)	1,214,923		
	TOTAL	**4,376,203**	**4,376**	**1,597,314**
3/23/07	DS-E (17:36)	1,704,540		
	DS-C (16:54)	1,610,683		
	DS-W (16:13)	819,162		
	TOTAL	**4,134,386**	**4,134**	**1,509,051**
	East			
	Center			
	West			
DIFFERENCE	***TOTAL***	**-241,817**	**-242**	**-88,263**
			% Loss	**5.53%**

Date	Location	Total (kg/day)	Total (mt/day)	Total (mt/year)
3/24/07	US-E (16:25)	1,275,103		
	US-C (15:32)	1,567,450		
	US-W (14:50)	1,433,470		
	TOTAL	**4,276,023**	**4,276**	**1,560,749**
3/24/07	DS-E (16:46)	1,527,788		
	DS-C (15:45)	1,788,588		
	DS-W (14:57)	1,020,472		
	TOTAL	**4,336,849**	**4,337**	**1,582,950**
	East			
	Center			
	West			
DIFFERENCE	***TOTAL***	**60,826**	**61**	**22,201**
			% Loss	**-1.42%**

Date	Location	Total (kg/day)	Total (mt/day)	Total (mt/year)
3/26/07	US-E (14:35)	625,574		
	US-C (15:12)	703,757		
	US-W (15:56)	546,882		
	TOTAL	**1,876,213**	**1,876**	**684,818**
3/26/07	DS-E (14:43)	712,598		
	DS-C (15:29)	762,425		
	DS-W (16:04)	463,194		
	TOTAL	**1,938,217**	**1,938**	**707,449**
	East			
	Center			
	West			
DIFFERENCE	***TOTAL***	**62,004**	**62**	**22,631**
			% Loss	**-3.30%**

Date	Location	Total (kg/day)	Total (mt/day)	Total (mt/year)
3/28/07	US-E (12:27)	238,136		
	US-C (11:53)	319,332		
	US-W (11:09)	236,844		
	TOTAL	**794,311**	**794**	**289,924**
3/28/07	DS-E (12:42)	166,353		
	DS-C (12:09)	374,629		
	DS-W (11:38)	205,804		
	TOTAL	**746,786**	**747**	**272,577**
	East			
	Center			
	West			
DIFFERENCE	***TOTAL***	**-47,525**	**-48**	**-17,347**
			% Loss	**5.98%**

Table 4-7c
Mass Balance Summary for Suspended Solids using OBS: Sixth Street Turning Basin
July 2007 - Low Flow Event

Date	Location	Total (kg/day)	Total (mt/day)	Total (mt/year)
7/9/07	US-E (10:08)	31,385		
	US-C (10:54)	21,996		
	US-W (11:36)	20,670		
	TOTAL	**74,051**	**74**	**27,029**
7/9/07	DS-E (10:47)	22,187		
	DS-C (11:15)	9,060		
	DS-W (11:55)	8,170		
	TOTAL	**39,417**	**39**	**14,387**
	East	-9,197		
	Center	-12,936		
	West	-12,501		
DIFFERENCE	***TOTAL***	**-34,634**	**-35**	**-12,641**
			% Loss	**46.77%**

Date	Location	Total (kg/day)	Total (mt/day)	Total (mt/year)
7/10/07	US-E (13:43)	28,263		
	US-C (14:29)	33,861		
	US-W (14:59)	28,246		
	TOTAL	**90,370**	**90**	**32,985**
7/10/07	DS-E (14:19)	21,509		
	DS-C (14:44)	29,044		
	DS-W (15:14)	13,340		
	TOTAL	**63,893**	**64**	**23,321**
	East	-6,754		
	Center	-4,816		
	West	-14,907		
DIFFERENCE	***TOTAL***	**-26,477**	**-26**	**-9,664**
			% Loss	**29.30%**

Table 4-8
Particle Size Distribution: Ojibway and Sixth Street Turning Basins - November 2006

Sample Type	Sample ID	Sample Location	% Clay (<2µm)	% Silt (2-50µm)	% Very Fine Sand (50-125µm)	% Fine Sand (125-250µm)	% Medium Sand (250-500µm)	% Coarse Sand (500-1000µm)	% Very Coarse Sand (1000-2000µm)	% Gravel (>2000µm)
Sediment Trap	SR DS 1	Downstream West	2.50	33.99	6.30	9.45	28.26	13.52	0.89	5.09
Sediment Trap	SR DS 3	Downstream East	2.09	32.87	5.64	17.45	29.86	3.52	2.01	6.56
Sediment Trap	SR TB Center 1	Turning Basin Center West	1.41	21.87	2.46	24.55	38.53	6.46	0.02	4.70
Sediment Trap	SR TB Center 2	Turning Basin Center Center	2.94	47.20	11.91	8.75	8.82	6.64	0.85	12.89
Sediment Trap	SR TB Center 3	Turning Basin Center East	4.69	46.52	9.90	14.91	16.03	3.93	1.28	2.74
Sediment Trap	SR TB North 2	Turning Basin North Center	4.76	59.24	9.30	4.85	2.82	0.49	2.43	16.11
Sediment Trap	SR TB North 3	Turning Basin North East	1.63	22.42	3.35	21.44	39.46	4.50	0.04	7.16
Sediment Trap	SR TB South 2	Turning Basin South Center	0.19	6.42	0.46	9.19	67.21	7.90	0.84	7.79
Sediment Trap	SR TB South 3	Turning Basin South East	3.64	54.66	11.34	1.44	0.84	0.94	4.07	23.07
Sediment Trap	SR US 1	Upstream West	4.37	66.86	15.12	6.14	5.21	2.30	0.00	0.00
Sediment Trap	SR US 2	Upstream Center	3.29	44.60	15.23	8.82	8.91	5.11	4.73	9.31
Sediment Trap	SR US 3	Upstream East	3.63	49.99	15.87	6.75	8.58	4.56	2.42	8.20
Water	D 111406 1045	Downstream	0.14	49.25	37.42	5.09	8.10	0.00	0.00	0.00
Water	DC 111506 1410	Downstream Center	0.14	55.69	34.92	9.26	0.00	0.00	0.00	0.00
Water	DE 111506 1445	Downstream East	0.19	64.22	30.35	5.24	0.00	0.00	0.00	0.00
Water	DS 112106 1215	Downstream	0.33	73.54	20.98	5.14	0.00	0.00	0.00	0.00
Water	DS 112106 1605	Downstream	0.22	58.56	37.29	3.93	0.00	0.00	0.00	0.00
Water	DS 112806 1030	Downstream	0.32	77.19	22.49	0.00	0.00	0.00	0.00	0.00
Water	DS 112806 1515	Downstream	0.39	78.02	18.94	2.65	0.00	0.00	0.00	0.00
Water	DW 111506 1252	Downstream West	0.41	78.58	21.02	0.00	0.00	0.00	0.00	0.00
Water	U 111406 1500	Upstream	0.01	6.13	8.12	8.10	77.64	0.00	0.00	0.00
Water	UC 111506 1625	Upstream Center	0.33	61.32	34.95	3.40	0.00	0.00	0.00	0.00
Water	UE 111506 1650	Upstream East	0.14	54.10	35.18	10.58	0.00	0.00	0.00	0.00
Water	US 112106 1010	Upstream	0.34	73.90	25.76	0.00	0.00	0.00	0.00	0.00
Water	US 112106 1420	Upstream	0.30	67.76	28.82	3.12	0.00	0.00	0.00	0.00
Water	US 112106 1420 DUP	Upstream	0.45	72.61	26.93	0.00	0.00	0.00	0.00	0.00
Water	US 112806 1330	Upstream	0.32	78.80	20.88	0.00	0.00	0.00	0.00	0.00
Water	US 112806 900	Upstream	0.44	86.50	13.06	0.00	0.00	0.00	0.00	0.00
Water	UW 111506 1520	Upstream West	0.15	46.81	37.52	15.52	0.00	0.00	0.00	0.00
Core	VC5-11.0-11.4	Ojibway Turning Basin	10.81	65.77	10.77	4.31	6.81	1.53	0.00	0.00
Core	VC5-18.5-19.0	Ojibway Turning Basin	12.22	78.71	8.52	0.33	0.20	0.02	0.00	0.00
Core	VC5-18.5-19.0 DUP	Ojibway Turning Basin	10.64	76.71	11.83	0.55	0.24	0.03	0.00	0.00
Core	VC5-00.0-00.5	Ojibway Turning Basin	8.78	59.90	13.11	7.87	6.33	3.57	0.44	0.00
Core	VC6-00.0-00.5	Ojibway Turning Basin	0.00	3.97	1.14	8.97	49.89	22.86	6.49	6.68
Core	VC6-03.2-03.7	Ojibway Turning Basin	11.99	68.67	5.18	4.86	8.33	0.97	0.00	0.00
Core	VC6-12.0-12.5	Ojibway Turning Basin	14.43	81.67	3.65	0.18	0.07	0.00	0.00	0.00
Core	VC6-12.0-12.5 DUP	Ojibway Turning Basin	12.57	81.67	5.43	0.30	0.03	0.00	0.00	0.00
Core	VC8-00.0-00.5	Ojibway Turning Basin	0.00	0.00	0.00	0.94	51.90	46.77	0.39	0.00
Core	VC8-00.5-01.0	Ojibway Turning Basin	0.00	1.76	0.61	2.02	44.18	37.68	4.62	9.13

Table 4-9
Particle Size Distribution: Sixth Street Turning Basin Sediment Trap Samples - July 2007

Sample Type	Sample ID	% Clay (<2µm)	% Silt (2-50µm)	% Very Fine Sand (50-125µm)	% Fine Sand (125-250µm)	% Medium Sand (250-500µm)	% Coarse Sand (500-1000µm)	% Very Coarse Sand (1000-2000µm)	% Gravel (>2000µm)
SR-TB-SOUTH-2	Turning Basin South Center	11.21	69.07	5.21	4.82	8.44	1.25	0.00	0.00
SR-US-3	Upstream East	10.14	79.18	8.36	1.06	1.03	0.23	0.00	0.00
SR-DS-1	Downstream West	11.32	64.64	8.56	5.23	7.11	3.14	0.00	0.00
SR-US-1	Upstream West	9.85	79.23	6.98	1.42	2.00	0.52	0.00	0.00
SR-DS-2	Downstream Center	10.56	67.94	6.66	5.23	8.17	1.44	0.00	0.00
SR-TB-NORTH-3	Turning Basin North East	10.53	74.01	10.18	2.99	2.06	0.23	0.00	0.00
SR-TB-NORTH-1	Turning Basin North West	9.76	77.20	6.42	2.83	3.41	0.38	0.00	0.00
SR-DS-3	Downstream East	10.81	70.45	9.72	4.37	4.01	0.64	0.00	0.00
SR-TB-CENTER-3	Turning Basin Center East	10.02	76.71	8.99	2.13	1.79	0.36	0.00	0.00
SR-TB-CENTER-3-D	Turning Basin Center East	10.13	73.62	10.60	2.98	2.13	0.54	0.00	0.00
SR-TB-NORTH-2	Turning Basin North Center	11.93	53.78	4.91	2.42	0.78	0.00	1.71	24.64
SR-TB-CENTER-2	Turning Basin Center Center	11.61	57.57	4.53	7.82	15.41	3.06	0.00	0.00
SR-US-2	Upstream Center	9.84	80.19	6.23	1.03	2.06	0.65	0.00	0.00
SR-TB-SOUTH-1	Turning Basin South West	12.11	65.74	7.08	6.43	7.30	1.34	0.00	0.00
SR-TB-CENTER-1	Turning Basin Center West	11.76	73.12	5.94	2.98	4.97	1.23	0.00	0.00
SR-TB-SOUTH-3	Turning Basin South East	9.99	68.00	7.91	5.55	6.94	1.61	0.00	0.00

Table 4-10
Particle Size Distribution: Sixth Street Turning Basin Bedload Samples - March 2007

Sample Type	Sample ID	Sample Location	% Clay (<2µm)	% Silt (2-50µm)	% Very Fine Sand (50-125µm)	% Fine Sand (125-250µm)	% Medium Sand (250-500µm)	% Coarse Sand (500-1000µm)	% Very Coarse Sand (1000-2000µm)	% Gravel (>2000µm)
Bedload	DBC-032307-1750	Downstream Center	9.93	84.96	4.66	0.13	0.3	0.02	0	0
Bedload	DBC-032407-1725	Downstream Center	0	4.82	0.32	34.97	55.29	4.6	0	0
Bedload	DBC-032607-1628	Downstream Center	0.17	8.47	1.02	24.59	49.38	8.49	2.26	5.62
Bedload	DBE-032307-1745	Downstream East	0.27	9.64	1.56	15.31	36.07	7.26	3.45	26.44
Bedload	DBE-032407-1720	Downstream East	0	0	0.03	22.87	69.45	7.65	0	0
Bedload	DBE-032607-1458	Downstream East	0.21	8.94	0.45	27.28	47.4	6.02	1.72	7.98
Bedload	DBW-032307-1800	Downstream West	0	6.89	3.06	10.45	31.71	13.83	6.07	27.99
Bedload	DBW-032407-1730	Downstream West	0.54	10.71	4.31	27.25	36.18	13.48	3.77	3.76
Bedload	DBW-032607-1632	Downstream West	0	3.51	0.4	31.44	53.98	9.38	1.29	0
Bedload	UBC-032307-1835	Upstream Center	0	1.05	0	7.55	57.6	17.07	6.11	10.62
Bedload	UBC-032407-1740	Upstream Center	0	0	0	6.5	66.46	26.63	0.41	0
Bedload	UBC-032607-1640	Upstream Center	0	0	0	3.81	65.44	28.44	2.31	0
Bedload	UBC-032807-1300	Upstream Center	0	0	0	2.06	69.96	27.93	0.05	0
Bedload	UBE-032307-1830	Upstream East	0	0.94	0	7.58	59.34	26.47	0.53	5.14
Bedload	UBE-032407-1738	Upstream East	0	1.12	0.09	11.42	66.47	19.26	1.64	0
Bedload	UBE-032607-1300	Upstream East	0	0	0	1.01	58.56	23.69	2.29	14.45
Bedload	UBE-032807-1355	Upstream East	0	0	0	1.78	59.65	33.4	0	5.18
Bedload	UBW-032307-1840	Upstream West	0	0	0.01	22.59	68.43	8.97	0	0
Bedload	UBW-032407-1745	Upstream West	0	0	3.8	26.21	61.8	8.19	0	0
Bedload	UBW-032607-1644	Upstream West	0	0	0	15.59	74.08	10.33	0	0
Bedload	DBC-032407-1725	Downstream Center	0.00	0.00	0.08	24.20	64.25	0.63	4.01	6.83
Bedload	DBE-032307-1745	Downstream East	1.87	21.18	8.87	7.83	10.58	10.69	3.73	35.25
Bedload	DBE-032407-1720	Downstream East	0.00	0.00	0.03	20.30	70.48	9.19	0.00	0.00
Bedload	DBE-032407-1720-D	Downstream East	0.19	4.61	0.69	17.48	65.82	7.05	Nill	4.16
Bedload	DBE-032607-1458	Downstream East	0.93	11.52	4.52	18.95	28.92	18.78	8.30	8.08
Bedload	DBW-032307-1800	Downstream West	0.39	7.61	3.48	2.75	5.94	9.17	4.63	66.03
Bedload	DBW-032407-1730	Downstream West	2.44	21.32	8.89	17.75	21.55	17.86	10.19	0.00
Bedload	DBW-032607-1632	Downstream West	0.91	9.94	3.58	21.52	36.30	19.45	3.61	4.69
Bedload	UBC-032307-1835	Upstream Center	0.00	3.13	0.94	4.73	60.75	21.47	0.77	8.21
Bedload	UBC-032407-1740	Upstream Center	0.00	0.00	0.00	5.76	63.20	21.21	Nill	9.83
Bedload	UBC-032607-1640	Upstream Center	1.06	7.15	0.90	5.01	64.08	21.76	0.04	0.00
Bedload	UBC-032607-1640-D	Upstream Center	0.00	0.00	0.00	5.72	70.67	23.61	0.00	0.00
Bedload	UBE-032307-1830	Upstream East	0.84	9.03	1.63	6.45	48.22	26.57	Nill	7.26
Bedload	UBE-032407-1738	Upstream East	0.00	1.00	0.00	9.91	58.32	15.36	3.49	11.92
Bedload	UBE-032607-1300	Upstream East	0.45	4.83	1.00	6.28	44.22	28.30	3.31	11.61
Bedload	UBW-0.2407-1745	Upstream West	0.22	4.02	0.08	29.26	63.46	2.96	0.00	0.00
Bedload	UBW-032307-1840	Upstream West	0.55	6.62	0.54	19.32	65.31	7.66	0.00	0.00
Bedload	UBW-032607-1644	Upstream West	0.00	1.07	0.55	17.08	63.43	8.81	Nill	9.06

Table 4-11
Dioxin/Furan Total TEQ Results: Sixth Street Turning Basin
November 2006 - Medium Flow Event

Sample Type	Sample Location	Sample ID	Date Sampled	Total TEQ (pg/g)
Bedload	Downstream Center	DC1114061335	14-Nov-06	760
	Downstream Center	DC1115061700	15-Nov-06	20187
	Downstream Center	DC1121061713	21-Nov-06	32593
	Downstream Center	DC1128061626	28-Nov-06	411
	Downstream East	DE1114061320	14-Nov-06	154
	Downstream East	DE1121061720	21-Nov-06	5837
	Downstream East	DE1128061620	28-Nov-06	422
	Downstream West	DW1114061342	14-Nov-06	92.6
	Downstream West	DW1115061715	15-Nov-06	145
	Downstream West	DW1121061708	21-Nov-06	275
	Downstream West	DW1128061630	28-Nov-06	24806
	Upstream Center	UC1114061655	14-Nov-06	305
	Upstream Center	UC1121061355	21-Nov-06	69.2
	Upstream Center	UC1128061225	28-Nov-06	63.7
	Upstream East	UE1114061700	14-Nov-06	9.8
	Upstream East	UE1121061400	21-Nov-06	26542
	Upstream East	UE1128061215	28-Nov-06	106
	Upstream West	UW1114061650	14-Nov-06	438
	Upstream West	UW1121061350	21-Nov-06	344
	Upstream West	UW1128061235	28-Nov-06	767
Sediment Trap	Downstream West	SR-DS-1	18-Nov-06	53.0
	Downstream East	SR-DS-3	18-Nov-06	10896
	Turning Basin Center West	SR-TB-CENTER-1	19-Nov-06	108
	Turning Basin Center Center	SR-TB-CENTER-2	19-Nov-06	249
	Turning Basin Center East	SR-TB-CENTER-3	18-Nov-06	100
	Turning Basin North Center	SR-TB-NORTH-2	19-Nov-06	1174
	Turning Basin North East	SR-TB-NORTH-3	18-Nov-06	651
	Turning Basin South Center	SR-TB-SOUTH-2	19-Nov-06	18189
	Turning Basin South East	SR-TB-SOUTH-3	19-Nov-06	1768
	Upstream West	SR-US-1	19-Nov-06	48.6
	Upstream Center	SR-US-2	18-Nov-06	102
	Upstream East	SR-US-3	18-Nov-06	40.7
Suspended Sediment	Downstream	D1114061045	14-Nov-06	8.20
	Downstream	D1115061010	15-Nov-06	12.5
	Downstream	DS-112106-1215	21-Nov-06	18.5
	Downstream	DS-112106-1605	21-Nov-06	6.91
	Downstream	DS112806-1030	28-Nov-06	1.72
	Downstream	DS112806-1515	28-Nov-06	5.12
	Upstream	U1114061500	14-Nov-06	19.0
	Upstream	U1115061520	15-Nov-06	7.13
	Upstream	US-112106-1010	21-Nov-06	2.82
	Upstream	US-112106-1420	21-Nov-06	4.51
	Upstream	US-112106-1420-DUP	21-Nov-06	3.07
	Upstream	US112806-1330	28-Nov-06	2.36
	Upstream	US112806-1330-DUP	28-Nov-06	1.59
	Upstream	US112806-900	28-Nov-06	2.76

Table 4-12
Dioxin/Furan Total TEQ Results: Sixth Street Turning Basin
March 2007 - High Flow Event

Sample Type	Sample Location	Sample ID	Date Sampled	Total TEQ (pg/g)
Bedload	Downstream Center	DBC-032307-1750	23-Mar-07	7.18
	Downstream Center	DBC-032407-1725	24-Mar-07	17.2
	Downstream Center	DBC-032607-1628	26-Mar-07	1059
	Downstream Center	DBC-032807-1340	28-Mar-07	1231
	Downstream East	DBE-032307-1745	23-Mar-07	495
	Downstream East	DBE-032407-1720	24-Mar-07	18.7
	Downstream East	DBE-032607-1458	26-Mar-07	4465
	Downstream East	DBE-032807-1343	28-Mar-07	40.7
	Downstream West	DBW-032307-1800	23-Mar-07	1448
	Downstream West	DBW-032407-1730	24-Mar-07	626
	Downstream West	DBW-032607-1632	26-Mar-07	48.4
	Downstream West	DBW-032807-1346	28-Mar-07	2356
	Upstream Center	UBC-032307-1835	23-Mar-07	37.8
	Upstream Center	UBC-032407-1740	24-Mar-07	34.6
	Upstream Center	UBC-032607-1640	26-Mar-07	14.2
	Upstream Center	UBC-032807-1300	28-Mar-07	8.51
	Upstream East	UBE-032307-1830	23-Mar-07	10720
	Upstream East	UBE-032407-1738	24-Mar-07	53.6
	Upstream East	UBE-032407-1738-D	24-Mar-07	30.4
	Upstream East	UBE-032607-1300	26-Mar-07	49.1
	Upstream East	UBE-032607-1300-D	26-Mar-07	67.9
	Upstream East	UBE-032807-1355	28-Mar-07	66.0
	Upstream East	UBE-032807-1355-D	28-Mar-07	11503
	Upstream West	UBW-032307-1840	23-Mar-07	28.2
	Upstream West	UBW-032407-1745	24-Mar-07	14.3
	Upstream West	UBW-032607-1644	26-Mar-07	60.0
	Upstream West	UBW-032807-1352	28-Mar-07	195
Suspended Sediment	Downstream	DS-032307-1140	23-Mar-07	35.2
	Downstream	DS-032407-1130	24-Mar-07	50.9
	Downstream	DS-032607-1020	26-Mar-07	35.8
	Downstream	DS-032607-1020-D	26-Mar-07	39.5
	Downstream	DS-032807-0940	28-Mar-07	12.2
	Upstream	US-032307-1100	23-Mar-07	3895
	Upstream	US-032407-1045	24-Mar-07	44.8
	Upstream	US-032607-0940	26-Mar-07	13.8
	Upstream	US-032807-0913	28-Mar-07	18.2

Table 4-13
Dioxin/Furan Total TEQ Results: Sixth Street Turning Basin
July 2007 - Low Flow Event

Sample Type	Sample Location	Sample ID	Date Sampled	Total TEQ (pg/g)
Bedload	Downstream Center	DC070907-071107-1440	11-Jul-07	1658
Bedload	Downstream east	DE071107-1435	11-Jul-07	267
Bedload	Upstream Center	UC070907-071107-1452	11-Jul-07	21.3
Bedload	Upstream East	UE070907-071107-1450	11-Jul-07	20.0
Bedload	Upstream West	UW070907-071107-1455	11-Jul-07	17.2
Sediment Trap	Downstream West	SR-DS-1	14-Jul-07	4206
Sediment Trap	Downstream center	SR-DS-2	14-Jul-07	323
Sediment Trap	Downstream East	SR-DS-3	14-Jul-07	213
Sediment Trap	Turning Basin Center	SR-TB-CENTER-1	15-Jul-07	79.6
Sediment Trap	Turning Basin Center	SR-TB-CENTER-2	14-Jul-07	80.6
Sediment Trap	Turning Basin Center East	SR-TB-CENTER-3	14-Jul-07	540
Sediment Trap	Turning Basin Center East	SR-TB-CENTER-3-D	14-Jul-07	116
Sediment Trap	Turning Basin North West	SR-TB-NORTH-1	14-Jul-07	68.4
Sediment Trap	Turning Basin North	SR-TB-NORTH-2	14-Jul-07	113
Sediment Trap	Turning Basin North East	SR-TB-NORTH-3	14-Jul-07	95.8
Sediment Trap	Turning Basin South West	SR-TB-SOUTH-1	15-Jul-07	70.8
Sediment Trap	Turning Basin South	SR-TB-SOUTH-2	15-Jul-07	77.9
Sediment Trap	Turning Basin South East	SR-TB-SOUTH-3	15-Jul-07	253
Sediment Trap	Upstream West	SR-US-1	15-Jul-07	109
Sediment Trap	Upstream Center	SR-US-2	15-Jul-07	66.6
Sediment Trap	Upstream East	SR-US-3	15-Jul-07	72.81
Suspended Sediment	Downstream	DS-070907-1030	09-Jul-07	48.6
Suspended Sediment	Downstream	DS-070907-1345	09-Jul-07	27.6
Suspended Sediment	Downstream	DS-071007-1000	10-Jul-07	9.85
Suspended Sediment	Downstream	DS-071007-1416	10-Jul-07	19.5
Suspended Sediment	Downstream	DS-071107-0930	11-Jul-07	17.3
Suspended Sediment	Downstream	DS-071107-1315	11-Jul-07	18.9
Suspended Sediment	Upstream	US-070907-0930	09-Jul-07	22.4
Suspended Sediment	Upstream	US-070907-1315	09-Jul-07	18.3
Suspended Sediment	Upstream	US-071007-0915	10-Jul-07	5.59
Suspended Sediment	Upstream	US-071007-0915-DUP	10-Jul-07	10.6
Suspended Sediment	Upstream	US-071007-1345	10-Jul-07	10.9
Suspended Sediment	Upstream	US-071107-0845	11-Jul-07	10.5
Suspended Sediment	Upstream	US-071107-0845-DUP	11-Jul-07	4.21
Suspended Sediment	Upstream	US-071107-1245	11-Jul-07	29.7

Table 4-14
Summary of t-Test Statistics: Sixth Street Turning Basin Samples

Event	Sample	Comparison	t-statistic	DF	2-tailed p
November 2006	Bedload	Upstream v Downstream	1.561	17.4	0.137
	Suspended Sediment	Upstream v Downstream	1.333	10.6	0.211
	Sediment Trap	Upstream v Downstream	0.957	1.02	0.511
	Sediment Trap	Turning Basin North v South	-1.555	1.13	0.343
	Sediment Trap	Turning Basin South v Center	3.085	1.13	0.176
	Sediment Trap	Turning Basin South v Center 2	-0.846	3.5	0.452
March 2007	Bedload	Upstream v Downstream	1.272	23.2	0.216
	Suspended Sediment	Upstream v Downstream	-0.710	3.21	0.526
July 2007	Bedload	Upstream v Downstream	3.863	1.01	0.159
	Suspended Sediment	Upstream v Downstream	1.822	11.9	0.090
	Sediment Trap	Upstream v Downstream	2.224	2.1	0.150
	Sediment Trap	Turning Basin North v South	-0.487	2.51	0.666
	Sediment Trap	Turning Basin South v Center	-0.387	4.95	0.715
	Sediment Trap	Turning Basin East v West	2.508	3.08	0.085
	Sediment Trap	Turning Basin West v Center 2	1.601	2.587	0.222

Table 4-15
Total Moisture and Total Organic Carbon: Sixth Street Turning Basin

Sample Event & Type	Location ID	Sample ID	Total Moisture (%)	Total Organic Carbon (mg/kg)
Sixth Street Turning Basin: March 2007 - Bedload	SR-DS-2	DBC-032407-1725	23.2	ND
	SR-DS-3	DBE-032307-1745	62.5	434000
	SR-DS-3	DBE-032407-1720	21.4	ND
	SR-DS-3	DBE-032407-1720-D	21	ND
	SR-DS-3	DBE-032607-1458	30.8	10500
	SR-DS-1	DBW-032307-1800	75.4	148000
	SR-DS-1	DBW-032407-1730	32.1	8520
	SR-DS-1	DBW-032607-1632	30.1	4450
	SR-US-2	UBC-032307-1835	22	4260
	SR-US-2	UBC-032407-1740	20.3	ND
	SR-US-2	UBC-032607-1640	17.5	ND
	SR-US-2	UBC-032607-1640-D	18.3	ND
	SR-US-3	UBE-032307-1830	23	ND
	SR-US-3	UBE-032407-1738	21.3	ND
	SR-US-3	UBE-032607-1300	26.4	ND
	SR-US-1	UBW-032307-1840	22.9	8140
	SR-US-1	UBW-032407-1745	19	ND
	SR-US-1	UBW-032607-1644	23.1	3450
Sixth Street Turning Basin: November 2006 - Sediment Trap	SR-TB-NORTH-2	SR-TB-NORTH-2	24.8	2590
	SR-TB-SOUTH-2	SR-TB-SOUTH-2	19.5	ND

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